SUMMER INSTITUTE IN

CULTURE OF EDIBLE MOLLUSCS

HELD AT

TUTICORIN RESEARCH CENTRE OF

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE

From 26 May to 24 June 1980

Central Marine Fisheries Research Institute

P.B. 1912, COCHIN - 682018, INDIA

Indian Council of Agricultural Research

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Contents

PREFACE

The Indian Council of Agricultural Research has been sponsoring Summer Institutes in different disciplines of Agriculture, Animal Science, and Fisheries, since 1967. The objectives of the Institute are:

1) to bring the knowledge of the subject of experienced teachers, research workers and technical personnel upto date.

2) to assist them improve the effectivesness through enlightened understanding of their subject and

3) to identify specialised fields of interest and give proper orientation to contemporary problems with the help of specialists in the fields.

These courses are organised during the Summer vacation so that the sponsoring Institutions and University Departments and Colleges may find it easy to depute teaching staff without affecting the teaching work.

The Central Marine Fisheries Research Institute, Cochin has conducted two such courses, the first in 1974 in "Coastal Aquaculture" and the second in 1977 in "Breeding and rearing of marine prawns", both at Cochin. The recently conducted Summer Institute in "Culture of Edible Molluscs" was the 3rd in the series. This was organised and run at Tuticorin which is to-day the leading centre of Molluscan research and culture work in the country. Molluscan culture has acquired considerable significance in recent years due to the high production potential of the culturable species such as mussels, oysters and clams. Our coastal, estuarine and backwater areas support good resources of molluscs showing a fast rate of growth and a high percentage of meat edibility and protein content.

The object of running the Summer Institute at Tuticorin was to provide an opportunity to the participants to get a deep insight into the various systems of Molluscan culture that have been developed in this country in addition to equipping them with upto date knowledge of status of Molluscan culture and recent advancements made in other parts of the world. Acquaintance with the problems of research and management and widening of knowledge in solving various problems arising out of culturing molluscs will help those attending the course to propogate molluscan culture through extension programmes and suitable curricular courses. The University teachers should be able to incorporate this subject matter in the curriculum, thereby enhance the teaching programme. The research workers participating in the course can also play a vital role in solving various problems closely associated with the development of Mariculture. Therefore, the course has been streamlined to satisfy all the above purposes. Although of a short duration of four weeks, efforts had been made to chalk out an effective syllabus wherein theoritical aspects had been convered in 20 lectures and field-oriented practical courses in 111 hours.

Although Central Marine Fisheries Research Institute has successfully carried out technical feasibility of culture of some species of bivalves, many basic problems such as effects of pollution, uptake of heavy metals and toxicants in animal tissues, histopathological studies of diseases that occur amongst the tended stock, problems of reproductive physiology, and genetic studies connected with evolving fast growing and disease resistant strains by cross breeding need more intensive investigations. To identify such problems and to assess the scope there can be no better forum than the Summer Institute course.

It is therefore envisaged that the participants should make a note of their fields of interest as the course advances and bring out their ideas during discussion hours. Although it may not be possible to find answers to their problems immediately it would be possible to develop new lines of work.

Accommodating all the participants in one place for the duration of Summer Institute has many advantages. From the point of view of fulfilling one of the objectives of the Summer Institute it promotes opportunities for discussions even outside the class room lectures and practicals. The participants may group themselves and organise free and frank discussions in the evenings or after dinner if necessary, inviting the specialist staff member to mediate and lead the discussion. Ear-marking library hours for extensive reading is another benefit the participants will have. Here again rare and important literature on the topics connected with the course of training and inter-related disciplines are made available at one place, the benefit of which the participants may not get in the place of their work. Field oriented practical classes and direct participation in the farming activities as envisaged under the Summer Institute course would give a direct sense of participation and provide necessary personal practical skill and knowledge on the process of implementation. It is hoped that with the above plan of action the course would become meaningful.

E.G. Silas
Director

Cochin.

EXCERPTS FROM THE INAUGURAL ADDRESS BY DR. E.G. SILAS
ON 26-5-1980

Dr. Thuljaram Rao, Mr. Nayar, Mr. Ambrose Fernando, Mr. Joseph, Mr. Chidambaram, Ladies and gentlemen,

Mr. Nayar, the Director of the Summer Institute has given me two tasks - one to inaugurate the Summer Institute, and the second to give a talk on the subject of culture of edible molluscs. I would like to touch upon a few aspects of culture of edible molluscs which are very relevant to our training programme which is to be inaugurated to-day. Firstly, this programme is primarily meant for those who could further take it for inclusion in academic course curricula to become part of major teaching programme. The Summer Institute should also draw attention to the new lines of research and development in this subject area. It is with this reason that we have invited most of the participants from the academic universities, Agricultural Universities and other departments which have programmes of this nature.

When the Indian Council of Agricultural Research sent round a circular and asked us to suggest a topic we felt that culture of edible molluscs is a vitally important area in which on going researches will have to be shared with those who would take the message and help in the overall future advancement of R & D and extension training in this field.

Culture of edible molluscs is very important from the point of view of production as no other animal gives such high biomass of production as the bivalves in culture system. Unfortunately in developing countries bivalves figure only as a subsistance fishery. In India it has formed the food of the poorest of the poor people living along certain parts of our coast. In short, molluscan fishery, particularly, for clams, oysters and mussels is in a state at which the prawn fishery was about 25 years ago. This comparison is mainly from the level of human consumption and acceptability. However, within the next decade, molluscs, especially mussels and oysters may also have a demand as much as prawns as the acceptability of molluscan meat within the country increases side by side with a growing demand for this product in the world market. This is the reason why CMFRI has given priority to the research programmes concerning the culture of various cultivable species of molluscs.

There is a global awareness on the importance of aquaculture to meet the world demand for fish and shell fish. Yields per unit area from aquaculture are much higher than traditional capture fisheries and on account of the uncertainties in the latter, more intensive efforts are going on for developing high production aquaculture systems. Development of inland aquaculture of fresh water fish and other organisms has a number of constraints and limitations, such as land and water use and management, conflict with agriculturists, pollution problem and so on. Coastal aquaculture extending to farming in the sea offers immense possibilities for development as most of the brackishwater areas, inundated coastal areas and the inshore waters where traditional fishing is not practised are unutilised or under-utilised.

Any technology in aquaculture developed for transfer to the coastal people who are living far below the poverty line, should be such that it can be easily assimilated and propagated. It is imperative that technology be low-cost. Fortunately in our national fisheries plan, we have given high priority to coastal aquaculture and as a result every maritime State is trying to set up Pilot Projects and production oriented units for prawn and finfish culture. We have nearly 2 million hectares of brackish water areas along our coast which could be fruitfully utilised for finfish and shellfish culture. This is in addition to the inshore coastal waters and mangrove fringed areas. At present only a few thousand metric tonnes of finfish are harvested from the brackish water areas through traditional farm culture systems adopted in parts of Kerala and West Bengal. An accelerated programme is needed to judiciously and expeditiously develop this vast potential. Thus today we are faced with a situation where we cannot afford to wait until 100 per cent results are obtained in research and production before training and extension programmes can be taken up. The priorities are such that it has become necessary to telescope research, production for economic viability, training and extension in such a way that simultaneous development in these different areas are occurring. The technical feasibility of culture operations when transferred as a low-cost technology as in the case of culture of mussels and oysters has been giving good dividends. It has not only given us confidence to go on large scale culture for testing the economic viability, but also get back an immense amount of feed back information.

At Tuticorin we have 3 major mariculture programmes underway viz., Pearl Oyster Culture and Culture Pearl Production; Edible Oyster Culture and Crab Culture. The technology of pearl culture developed indigenously at the Centre is being improved and it is attracting the attention of the entrepreneurs who have expressed interest for taking up the technology in large-scale. On the other hand, the edible oyster culture has attracted the small fishermen and today in the Institute's Lab-to-Land Programme at Tuticorin about 20 families are involved with oyster culture. They are keenly interested in the whole process and the Institute is trying to find suitable market avenues for the sale of the cultured oysters.

At other centres particularly at Calicut we have been able to successfully demonstrate open sea mussel culture (the green mussel <u>Perna virdis</u>) which has been taken up by about 30 families of traditional fishermen employed in diving and picking mussel from the sea bed. Product development and marketing are related problems in this sector which need our priority attention. New techniques of having submerged rafts which could be utilised for suspended culture of mussels and oysters throughout the year are also ~~been~~ being developed. The Research and Development going into this entire system is a continuous process and the Institute hopes to come up with newer innovations for the better utilisation of our brackish and coastal waters.

Recently I had occasion to visit some of the aquaculture facilities in Japan, United States of America and the United Kingdom. I find that the systems that we are developing in this country in mariculture are aimed at evolving low cost technologies and thereby are very unique. The production systems that I found in the developed countries are very expensive which may not be relevant to our situation. However, we are blessed with many desirable cultivable species of molluscs, warmer highly productive waters for phenomenally faster growth and relatively unpolluted waters as plus points. The participants in this Summer Institute would be learning and seeing some new things that they may not be finding in the books. As a follow up programme to this course we would advise the university teachers, including those from the Agricultural Universities to be in touch with us so that more information as and when developed by the Institute could be passed on to them to upgrade the teaching programmes.

There are many problems that could be tackled by the academic universities in basic research problems concerning aquaculture of molluscs. As participants in the Summer Institute you will have the benefit of hearing about this not from the theoriticians, but from my colleagues who have developed these systems, and may be considered leaders in this country in mariculture. I hope you will be able to take advantage of this expertise during your stay here. I hereby inaugurate this Summer Institute and wish you all well.

DR. J. THULJARAM RAO'S PRESIDENTIAL ADDRESS ON 26-5-1980

Director of the Central Marine Fisheries Research Institute, Dr. Silas, Staff of this Centre, participants of the Summer Institute programme, Ladies and gentlemen,

I appreciate the gesture on the part of Dr. Silas who has asked me to preside over the inaugural function of this Summer Institute in culture of edible molluscs. This subject naturally brings to my mind immediately the question of food and nutrition in the world particularly in our country. On the agricultural side 50% of the world's food production and consumption comes from cereals, pulses, oil seeds and the other 50% is derived from animal husbandry, poultry, and fishes. During the last two decades there has been a steady and sure switch over from the agricultural production and consumption to animal production and consumption. While in the developed countries this is going on very fast, we are still to catch up with the developing countries since we are bogged down by our own religious sentiments to vegetarian diet. The animal protein is more nutritive than the vegetable protein besides being more concentrated thereby reducing the bulk; in other words less consumption but more nutritive.

One can argue on the question whether it is the energy that is important or whether the protein content that is important as a source of nourishment, whether the calories can give enough protein by themselves or whether there should be specific protein content to sustain a healthy living. Naturally, attempts have been made to increase protein contents of vegetables, particularly of the amino-acids fractions. But it is felt that it is the calories that are important than the actual protein content. It is said "take care of the calories; the protein will take care of itself". As regards the percentage of energy derived from any food products fishes come first. We all know 2/3 of the earth's surface is under sea water. Marine fisheries has got an important role in future animal food production to keep pace with the human population growth in developed, developing and underdeveloped countries. We have to maintain a standard of living consistent not only with the health requirements but also with the cost of living also. Of course as far as marine fisheries are concerned the most important are the finfishes. The fatty fishes give about 46% of energy derived while the dried fishes give as much as 62%. In this context mariculture acquires special significance in a country like ours where we have a long coast-line which has not been tapped properly. In our country possibilities of culture are enormous and the CMFRI has done a good job in developing transferable technology for the culture of finfishes and shell fishes. In many Centres already such transfer of laboratory technique to field has taken place and with monetary encouragement by way of initial inputs as envisaged by the Lab-to-Land Programmes of the ICAR, these are bound to expand and become a profitable avocation to fisherfolk taking up coastal aquaculture. If the quality developed is of good standard, free of diseases and with high percentage of protein content, export avenues can be explored fetching lucrative returns. Local marketing should also to be encouraged and considerable extension work appears necessary. There has always been a feeling that edible molluscs are only fit for consumption by the very poor section of the society. It is looked down upon by the lower, middle and upper class people for reasons of their own. People have to be educated that the molluscs have been cultured in hygenic condition thus creating quality consciousness and eating consciousness among the upper class so that we might be able to develop the edible molluscan culture industry. It is in this context that I come into play in my humble way by coordinating the various Lab-to-Land Programmes. Scientists, who are the originators of improvement and finding new technology, themselves go to the field, talk to the receiving end, transfer the technology with their own minds and hands and thereby there is a quickening of the process instead of the technology trying to filter through the extension side. I must congratulate Dr. Silas in that CMFR Institute was the first to take the Lab-to-Land Programme in right earnest and make the fishermen understand and take to prawn culture, mussel culture, and oyster culture. Majority of fishermen are landless labourers. If we can do something for them by educating them in culturing edible molluscs and improve their lot the scientific community would have done a great deal not only for them but also for the Nation.

The above ideals and thoughts have been imbibed in the techniques developed in molluscan culture and the Summer Institute participants will learn a lot about them in the next 4 weeks. I wish them all a useful session.

SYLLABUS AND MEMBERS OF FACULTY

THEORY

1. Introduction to the course:

Aims and objectives of the course - coastal aquaculture and its significance - present status in India in relation to other countries - need for development and establishment of culture of molluscs in India - scope of development. — 1 hour

2. A brief review of molluscan culture in the world:

Historical background of various cultivated species - methods adopted - species cultivated yield and results - contribution of culture fisheries to world production. — 1 hour

3. Present status of molluscan fisheries and culture in India:

Edible oysters, clams, mussels, pearl oysters, cephalopods, chanks and other valuable species. — 1.30 hours

4. Taxonomy and ecology of cultivable molluscs:

Systematics - morphology - ecology — 1.30 hours

<table>
<tr><td>5. Fishery and biology of edible oysters</td><td rowspan="5">(Distribution - natural stock - exploitation and fishery - present status - food and feeding habits - growth - condition factor - maturity - fecundity - spawn- ing - fertilisation and development - larval history)</td><td>1 hour</td></tr>
<tr><td>6. Fishery and biology of mussels</td><td>1 hour</td></tr>
<tr><td>7. Fishery and biology of clams and cockles</td><td>1 hour</td></tr>
<tr><td>8. Fishery and biology of pearl oysters</td><td>1 hour</td></tr>
<tr><td>9. Fishery and biology of eephalopods</td><td>1 hour</td></tr>
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10. Technology of edible oyster culture	Various methods of culture - stake culture - rope culture - bottom culture - pen culture - interim culture - indoor culture - art of farm management	2 hours
11. Technology of mussel culture		1.30 hours
12. Technology of pearl culture		1.30 hours
13. Technology of clam and cockle culture		1 hour
14. Technology of cephalopod, scallop and abalone culture		1 hour

15. Seed production and hatchery development:

Natural sources of seed - collection technique - types of spat collectors - transport - hatchery methods - role of phytoplankton as food for the larvae - techniques of algal culture. — 2 hours

16. Shell fish diseases and their control:

Fouling - mass mortality - etiology - prevention - treatment — 2 hours

17. Harvesting:

Techniques of harvest - post harvest technology - depuration — 1 hour

18. Processing, preservation and marketing:

Different processing and preservation practices - marketing problems and strategy — 1 hour

19. Economics of production and socio-economics of culture: — 1 hour

20. Guest lecture - Problems related to seed procurement for culture of marine edible bivalve molluscs. — 2 hours

TOTAL — 26 hours

PRACTICAL

21.	Identification of edible and commercial molluscs	3 hours
22.	Dissection of edible oysters, mussels, clams, cephalopods and pearl oysters for gonadial maturity and gut content analysis	3 hours
23.	Culture of phytoplankton	2 hours
24.	Transplantation of seed mussels on ropes and suspension in raft	3 hours
25.	Spat collection techniques: Different materials used in spat collection - fabrication of cages - lime coating of tiles - preparation of rens - laying of spat collectors	9 hours
26.	Oyster culture: Rack erection - cage suspension and stocking - cleaning - predator control - purification process - oyster shucking.	22 hours
27.	Pearl culture: Construction of raft - maintenance - plankton and hydrological data collection	3 hours
28.	Pearl oyster surgery: Narcotisation - use of special instruments- graft tissue preparation - implantation of nuclei - post operational care	18 hours
29.	Collection of clam seeds and transplantation technique	6 hours
30.	Visit to chank godown and local fisheries institutions	6 hours
31.	Field trips to Cape Comorin and Vizhinjam for mussel collection and farm work	18 hours
32.	Group discussion on week ends and library work	18 hours
33.	Evaluation test	3 hours
	TOTAL	114 hours

MEMBERS OF FACULTY

Topics

(The number indicates the items as given under syllabus)

	Theory	Practical
Dr. E.G. Silas	1	
Shri K. Nagappan Nayar	3,10,18	26,32,33
Dr. K. Alagarswami	2,8,12,15	22,27,28
Shri S. Mahadevan	4,5,16,17	21,25,26
Shri K.A. Narasimham	7,9,13,14	26,29
Dr. P.S. Kuriakose	6,11,19	24,31
Shri K.K. Appukuttan		31
Shri A.C.C. Victor		22,27,28,30
Shri D.C.V. Easterson		22,23,26
Shri K. Ramadoss		25,29,30
Shri A. Chellam		21,23,27,28
Shri P. Muthiah		25,26,30
Shri M.E. Rajapandian		25,26,31
Shri S. Dharmaraj		21,22,28
Shri T.S. Velayudhan		21,22,28

PARTICIPANTS

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2. Shri A. Bastian Fernando,
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3. Dr. M.J. John,
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   Jaipur.

4. Dr. R.K. Mishra,
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   Post Graduate Department of Zoology,
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   Darbhanga.

5. Shri K.M. Mohamed Magdoom,
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6. Shri D.V. Nandasana,
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   Gujarat Fisheries Aquatic
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7. Shri B. Pragasam,
   Research Assistant,
   Marakkanam,
   S.A. District.

8. Shri M.N. Prasad,
   Junior Research Fellow,
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   Rajkot.

9. Shri S. Rajagopal,
   Research Fellow,
   CAS in Marine Biology, Marine Biological Station,
   Annamalai University, Portonovo.

10. Shri D. Samuel,
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11. Shri G. Shyam Sunder Reddy,
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C.K.M. College,
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12. Shri N. Siva Prasad Rao,
Head: Department of Zoology,
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13. Shri K. Sudhakaran,
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Pilot Project for mussel culture,
Vizhinjam.

14. Dr. V. Sundaraj,
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Fisheries College,
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15. Shri G. Venkatraydu,
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Department of Zoology,
Andhra University,
Waltair.

16. Shri Vibhas Mujumdar,
Senior Research Fellow,
Department of Limnology & Fisheries,
University of Udaipur,
Udaipur.

PROCEEDINGS OF THE SUMMER INSTITUTE

This Summer Institute was sanctioned by the ICAR recognising the tangible results achieved by the CMFRI towards culturing edible molluscs in our country, opening up possibilities of intensive culture of selected species of molluscs. Tuticorin Research Centre has played a stellar role in developing culture techniques for edible oyster and pearl oyster, in addition to functioning as a pivotal centre for coordinating research projects connected with mussel and clam culture of this Institute in other parts of our country. Therefore, it was very apt to have selected Tuticorin to organise and conduct the Summer Institute with the help of identified expertise serving as staff members to impart updated knowledge to participants selected from various fisheries departments, academic universities and Agricultural Universities who have fisheries educational courses. The idea was to equip the participants with necessary theoretical background information and impart field training in the practical methods of culture and allied techniques, so that when they get back to their respective departments, the teaching staff can project the subjects in their proper perspective to the pupils. The departmental staff can give proper orientation to their approach in developing mariculture techniques and the research workers can take up some of the fundamental yet vital subjects connected with the culture aspects and fill the gaps in our knowledge.

Keeping the above objectives in view, the syllabus and schedule of work was prepared allotting 114 hours for practical work and 26 hours for theory lessons. Sufficient time was allotted for library work and discussion. Field visits for on the spot studies for obtaining first-hand information and one special guest lecture to stimulate further interest and ideas were also included in the curriculum. 16 staff members of CMFRI were appointed to handle theory and practical classes (Section 4).

16 participants were selected (Section 5), of whom all but four could reach Tuticorin at the time of inauguration. The course was inaugurated on 26.5.1980 at 3.00 P.M. by Dr. E.G. Silas, Director of CMFRI and Dr. Thuljaram Rao, Zonal Coordinator of Lab-to-Land Programme of ICAR presided over the function. In his presidential address Dr. Thuljaram Rao traced the genesis of agricultural advancement in our country since Independence and emphasised the paramount need to maximise sea food production to meet animal protein requirements for human nutrition. Programmes like "Lab-to-Land" launched by ICAR are positive steps taking us closer to achieving this objective. Dr. Silas in his inaugural address highlighted the high production rate achieved by culture systems particularly the molluscan forms like mussels and oysters and observed that coastal aquaculture is fast catching up in our country following the success achieved by the CMFRI in prawn culture, mussel culture, oyster culture, pearl culture and seaweed culture. The need for evolving low cost technology, hatchery production of seeds to meet demands of culturists and intense research and extension work to avoid economic losses to fish farms due to diseases amongst the tended stock were also emphasised.

Books, brochures and other Summer Institute course materials were distributed to the participants present. The remaining participants who were delayed due to transit travelling reservation difficulties joined either the next day or the day after.

Of these only 15 could complete the course as one of the participants fell ill and rejoined only after 20 days. Lodging facilities were arranged at Ananda Lodge to all except two local participants. Transport facilities to and from the Research Centre were given whenever occasion demanded. Since it was not possible to organise common boarding facilities, all participants were given Rs.15/day in lieu of boarding and incidental pocket expenses.

As regards the age of the participants they were of age group between 23 - 40. 13 of them were Master's Degree holders and three

Ph.D's. Participants comprised of four Research officials from State Fisheries Departments, four Senior Research Scholars, one senior staff of Fisheries College, one from our Institute and the rest senior staff of Zoology departments of Universities and affiliated colleges from various States. Geographically 5 were from Tamil Nadu, 2 from Kerala, 3 from Andhra, 3 from Gujarat, 2 from Rajasthan and 1 from Bihar.

In all 20 lectures of duration of 1 - 2 hours each by staff members, one special lecture for 2 hours by Shri K.V. Rao, Retired Emeritus Scientist given on 12.6.1980 and 12 practicals extending for 111 hours were held. The participants visited Vizhinjam and Cape Comorin for special training in mussel culture from 9.6.1980 to 11.6.1980. A trip was arranged on 16.6.1980 to "Van Tivu" by launch for studying clam culture. The participants were also taken out to sea on 29.5.1980 for hydrographical data collection and to Harbour basin for field collections.

Facilities for screen projections of colour transparencies and slides were provided for lecturers. Week-end seminars were conducted to enable the participants to lead discussions on culture problems. Analysis of the evaluation test sheets revealed that all participants evinced keen interest in culture techniques. The Institute's help and facilities to fishery science students through short-term practical training programmes in edible molluscan culture techniques was desired by the teaching staff of colleges. All the participants, it is gratifying to record, were unanimous in their opinion that the Summer Institute had been very useful to them. The participants cooperated and evinced very keen interest during the entire course which is much appreciated.

The valedictory of the Summer Institute was held on 24.6.1980. Mr. V.V.D. Nityanandam, B.A., President, Tuticorin Chamber of Commerce & Industry delivered the valedictory address and distributed the course certificates to the participants. Dr. E.G. Silas, Director, CMFRI presided over the function. The CMFRI places on record its gratitude to the ICAR for sanctioning the Summer Institute and thanks the various sponsoring authorities for sending the participants.

A BRIEF REVIEW OF MOLLUSCAN CULTURE IN THE WORLD

K. ALAGARSWAMI

The oysters, mussels, clams, cockles, scallops and abalones are the food molluscs which are produced through aquaculture in several parts of the world. Oysters are among the earliest invertebrates produced by aquaculture and oyster culture dates back to the Roman days of 100 B.C. In spite of its antiquity application of modern technologies for the production of molluscs has been relatively recent.

The world fish production through aquaculture is a little over 6 million tonnes. The molluscs alone account for about 1.05 million tonnes or 17.2% of total aquaculture production. Oysters and mussels form the two major groups accounting for about 56% and 31% of the total molluscs production respectively. Scallops, clams and cockles together contribute to the remaining 13%.

OYSTER CULTURE

Japan

The major species used in culture in Japan is *Crassostrea gigas*, the Pacific oyster. The technology employed is highly sophisticated compared to the practices followed in other countries, including the USA. The industry is concentrated in Miyagi, Hiroshima and Kumamoto prefectures. Five different methods are employed in oyster culture: Bottom sowing, stick, rack, long line and raft culture. The bottom sowing method is the simplest of all and the earliest to be practised in Hiroshima. However, the modern oyster culture depends on raft and long line culture methods, accounting for 64% and 11.6% of the total area used in oyster culture. These methods have the advantages of expanding the area of operation to the deeper waters, using entire water column for increasing production and also for controlling the predators. The seed collection industry functions independent of oyster culture for the market. Although hatchery technology has been developed, for commercial production of seed hatcheries have not become popular. The seed of C. gigas is also exported to USA, Canada, France and other countries. The oyster spat are collected on shell strings using scallop shells or on plastic mesh collectors, called Netron. Oyster production in Japan stood at about 266,000 tonnes in 1968 after which there has been a decline due to pollution and other problems. The average yield under long line culture is as high as 26,000 kg meat weight/ha/annum which is the highest yield in the world.

U.S.A.

The culture industry is spread along both the coasts of USA. The American oyster, Crassostrea virginica is cultured on the Atlantic coast, and the Pacific oyster C. gigas along the Pacific coast. The latter was introduced from Japan and has established itself and is breeding successfully. About 60% of the oyster production comes from the natural stocks on the state-owned intertidal or subtidal beds which are harvested by licensed fishermen, and 40% of production comes from the privately owned or leased beds. The oyster industry is based entirely on on-bottom culture. Long-Island on the Atlantic coast and Washington on the Pacific coast are the most important oyster production centres, although it is practised at several other places. Even by this unsophisticated bottom culture method an average production of 5000 kg of meat/ha/year is obtained from the Atlanctic coast due to intensive management practices. The total oyster landings of USA stood at 326,000 tonnes (round weight) in 1972.

Major technological advances in oyster culture have been in the direction of artificial breeding production of seed and disease control. Commercial oyster hatcheries have been established both on the Atlantic and Pacific coasts and they are so versatile that they can produce seeds of oysters of different species, clams and abalones.

A completely closed cycle shellfish factory has been tested at the University of Delaware where the production through the whole life cycle of the oyster is controlled. Great strides have been made in the control of predators such as oyster drills and starfish and in understanding the causes of diseases and mass mortalities.

France

Two major species of oysters traditionally grown in France are the flat oyster Ostrea edulis and Portuguese oyster C. angulata. In the recent years C. gigas has been introduced. The Bay of Arcachon on the southwest part of France on the Atlantic coast and the Gulf of Morbihan on the southwestern part of Brittany are the most important regions for oyster culture in France. Collection of spat on lime coated, semicylindrical ceramic tiles which was introduced at Arcachon in 1857 is still being continued with little change. However, for the collection of seed of Portuguese oyster, shell bags have been found to be more efficient. The spat removed from the tiles are grown by on-bottom culture in oyster parks in the harbour and estuaries. The last one year of culture is done in small marshy ponds called "claires" for the fattening and greening of oysters. Production of oyster has fluctuated very highly in France due to large scale mortalities and disease problems. In 1975 the production was 71,000 tonnes. The average yield is 1000 kg meat weight for C. angulata and 250 kg for O. edulis per ha/year.

Other countries

The Republic of Korea produces about 73,000 tonnes using C. gigas under raft culture. In Australia the Sydney rock oyster C. commercialis is used in culture by the stick and tray methods and the production is around 10,000 tonnes. The slipper oyster C. eradelie is used in Philippines. In the recent years, Cuba and Venezuela have made substantial progress in the culture of mangrove oyster C. rhizophorae. In the Netherlands and Spain O. edulis is grown by on-bottom culture method. Mexico produces 45,000 tonnes of oysters, Thailand about 23,000 tonnes, Taiwan about 14,000 tonnes, Canada about 5,000 tonnes and U.K. about 3,000 tonnes.

MUSSEL CULTURE

In terms of production potential, culture of mussel assumes more importance even over the oysters. The world production of mussels ranges between 300,000 and 400,000 tonnes and the large-scale operations are confined to the temperate waters of Europe. Spain with 160,000 tonnes leads in mussel production, followed by the Netherlands (100,000 tonnes), Italy (30,000 tonnes) and France (17,000 tonnes), Federal Republic of Germany, Korea, Chile, Yugoslavia, Philippines and New Zealand are the other countries where mussel culture is practised. Unlike in the case of oysters with several species, a single species of the blue mussel <u>Mytilus</u> <u>edulis</u> contributes nearly to the total world production of mussels. The mediterranean mussel <u>M</u>. <u>galloprovincialis</u> and the green mussel <u>M.smaragdinus</u> are the other two important species. The former is closely related to the blue mussel.

<u>Spain</u>

The Galician Bays of Spain are the most important mussel farming centres of Spain, mussels are grown in rafts, the construction of which has undergone several improvements and steel structures are used today. Mussel seed is collected both from the rocky intertidal areas and on ropes suspended specially for the purpose from the floating mussel parks. The seed collected from rocks are wrapped around thick ropes and secured by fine, large mesh rayon netting which disintegrates within 24 hours of being placed in sea water, by which time the young mussels have attached themselves to the ropes. Spat collected on ropes are left to grow. When the clumps of mussels become large, the peripheral layers are removed and put on new ropes. Harvest is done by cranes when the mussels reach 7.5 - 10.0 cm. The rate of production is 300 tonnes meat/ha/year. Since mussels depend for their food on the first link of the food chain (phytoplankton and organic detritus) and plenty of food is available in the water column such high production rate is achieved.

Netherlands

Mussel farming in the Netherlands is more than a century old. The seed grounds are public beds and the Government permits collection of seed during short, well defined periods. The mussel farmers take the seed to their private plots and spread them. The half grown mussels are transferred to fattening grounds. Finally, after harvest, the mussels are kept in cleansing grounds before they are sold. The mussel industry has become highly mechanised. Seed collection and harvesting are done by mussel boats by dredging. Zeeland and Waddenzee are the two important mussel producing centres. The Dutch-style of mussel farming is a semi-culture operation depending on transplantation of seed from natural beds to better growing and fattening beds.

France

Mussel farming in France starts with the story of the Irish sailor Patrick Walton who in 1235 was shipwrecked in the Bay of Aiguillon and found good settlement of mussels on poles. Since then culture of mussels on rows of poles called the "Bouchots" has become the practice. Earlier seed was collected on poles planted in muddy areas but this has already been replaced to a large extent by collecting seeds on coco fibres stretched out horizontally. Planting poles has been mechanised to a certain extent and long tubes of nylon netting are used to attach mussels to the poles of bouchots. The north coast of Brittany is the chief mussel producing area. However, important seed collection centres are located in La Rochells in southern France. The mussel reaches the marketable size of 5 cm in about one year. Average production rate in bouchot culture is 2250 kg meat weight/ha/year.

Italy

In Italy, mussel farming is done by the hanging culture method. In the sheltered areas where mussel farming is practised the bottom is predominantly soft and muddy. The mussel parks comprise networks of poles connected with horizontal ropes. From these ropes strings of mussels are suspended. A special type of rope is stretched around the parks to collect the seed. The important areas of mussel farming are Chioggia-Venezia-Trieste, the region of Taranto, the Gulf of La Spezia, the area of Napoli and also the regions of Olbia and Varano. The Italian mussel production is around 30,000 tonnes.

Philippines

The Philippines is one of the very few countries in the tropical region which has developed mussel farming. The green mussel M. smaragdinus is farmed in the sub-tidal area of Bacoor Bay near Manila. Bamboo poles are erected in muddy areas and seed mussels settle on the poles and grow until marketable size. Divers are engaged both for staking the bamboo poles and for harvesting the mussels. It takes about 6 months for the mussels to reach the marketable size of 4 - 6 cm.

Other countries

Mussel culture is also done in Federal Republic of Germany (annual production about 14,000 tonnes), Republic of Korea (5,600 tonnes), Chile (1,300 tonnes), Yugoslavia (300 tonnes), New Zealand (200 tonnes) and Singapore.

CLAM AND COCKLE CULTURE

Culture of clams is next only to that of oysters in antiquity. Clam culture is widely practised in Japan and other countries of Asia and also the United States. The principle of clam culture remains still one of transplantation of seed from slow-growing beds to fast-growing beds.

Japan

Although about nine species of clams are cultured in Japan, the "Asari" clam Tapes japonica forms the most important species. The beds are prepared by ploughing the foreshore area with tractor to loosen the soil and to eliminate weeds. Clam culture is restricted to waters less than 25 cm deep at low tide. The bed is left undisturbed for a week and seed clams (T. japonica) of 1.5 cm size collected from the breeding areas are sown by hand at the initial stocking density of 1 - 4 litres/m^2. The clam grows to the marketable size of 4.0 cm or more in 22 months. Hand tools or simple dredges are used for harvesting.

Malaysia

The culture of blood clam or "Cockle", Anadara granosa, is one of the important avocations in coastal aquaculture in Malaysia. About 2000 ha of estuarine mud flats in the states of Perak and Selang are used in cockle culture. The spat density in reproductive beds is as high as 10,000 seed/m^2 or more. Seed of 4 - 10 mm (4 months old) size are collected using a fine mesh wire scoop and stocked in otherwise barren beds at an initial density of 1000 - 2000/m^2. The clams are grown for a period of 8 - 9 months when they reach the minimum legal size of 31 mm. Harvest is done with a wide mesh wire scoop. The average rate of production is 20.7 tonnes/ha/annum. The total annual production is about 28,000 tonnes (1975).

Other countries in Asia

Clam culture is also practised on a smaller scales in Taiwan, Republic of Korea, Thailand and Philippines. In Taiwan, the hard clam Meretrix meretrix, and the blood clam, Anadara granosa are cultured in about 1829 ha of area in western and northern coasts of Taiwan. The production is about 15,000 tonnes per annum. In the Republic of Korea, clams cultured are Meretrix lusoria, Venerupis japonica and Anadara bisenensis. The annual production is about 25,000 tonnes. The "cockle"

A. granosa is cultured in Thailand in about 625 ha in the estuaries of Mae Klong and Petchburi rivers. The duration of culture is about 8 - 12 months.

U.S.A.

Culture of the quahog, Mercenaria mercenaria is important along the Atlantic Coast of the United States of America, particularly in New England and Long Island Sound. The same primitive method of bottom culture as for oysters is used in clam culture. Seed clams of 3 - 12 mm size are scattered in the shallo water area and allowed to grow to marketable size (50 - 63.5 mm) which requires 5 - 8 years. Hatcheries are available for commercial production of clam seed. Hatchery seed planted in Florida reach marketable size in 2 years time. The soft-neck clam Mya arenaria is second in importance and culture of this clam is concentrated in Maine. The market size is reached in about 3 - 4 years.

Experimentally the quahog has been grown in sewage tanks at Poole Harbour. Work on clam genetics and cross-breeding has made some progress.

SCALLOP CULTURE

Japan leads in scallop culture, with the species of deep-sea scallop, Patinopecten yessoensis. The scallops are grown in sandwichtype frame nets and wire boxes under raft culture. The annual production is about 62,600 tonnes. In U.S.A. the bay-scallop Argopecten irradians is cultured on a very small scale.

ABALONES

At least eight species of the gastropod abalone occur in the Japanese waters. However, success has been achieved in rearing of Haliotis discus, the most important species. Hatchery technology is used for production of abalone seed. When they are 1.5 - 2.0 cm they are sold to fisheries co-operative societies. Growing abalone to commercial size under controlled conditions is too expensive and hence natural beds are stocked with the hatchery-raised seed. The recapture rate is about 10% of the seed in 2 - 3 years when the abalones reach 12 cm or more. Experimentally full hanging culture of abalone is done at the Oyster Research Institute, Kesennuma.

California has an important natural fishery for abalones, next only to that of Japan. Culture of the red abalone Haliotis rufescens is done in the Morro Bay area where a hatchery also functions.

CEPHALOPODS

Culture of octopus, squid and cuttlefish is still in the initial stage of development. Japan has taken a lead in this for the culture of squid Sepioteuthis lessoniana and cuttlefishes Euprymna, Sepia and Sepiella. Both egg capsules and young ones collected from nature are reared in tanks. Starting with an initial weight of 4 grams, the squid attains 500 to 700 grams in about 5 months which is the marketable size. Larvae are fed with live Mysis and the grown ups are supplied with shrimp and fish meat. The Republic of Korea has taken up culture of the octopus Polypus vulgaris. In the U.S.A., the squid Sepioteuthis sepioidea is cultured for research purposes and not commercially. From egg to maturity the squid takes about 5 months to grow.

GENERAL REMARKS

From the above review it emerges that molluscan culture is practised in many parts of the world. It is done on an extensive scale in the temperate and sub-tropical regions, particularly along the Atlantic coast of U.S.A. and in Japan for oysters and clams, and in Europe for oysters and mussels. In the tropics, South-east Asia has a culture industry predominantly based on clams and oysters.

The concentration of molluscan culture industry, as stated, is in the temperate region. Highly evolved techniques of hatchery production of seed, improved and intensive farming practices, predator control etc., are employed in these areas. The major problem is one of slow growth of the organisms and it takes between two and six years for the harvest. On the other hand in the tropical waters the techniques employed are of a primitive nature. But the advantage is the fast growth of the organisms and the culture duration is hardly from 6 to 12 months. There are immense possibilities of increasing production of molluscs in the tropical region by bringing in additional areas and adoption of improved technologies. However, there is a social problem of enlarging the consumption of cultured molluscs by the people and the economic problem of realising remunerative prices.

Perhaps India has one of the highest potentials for production of molluscs in this region having a variety of species exploited at subsistence level. Adopting simple farming practices developed in the recent years it would be possible to increase production. The mussel gives one of the highest production rates in raft culture and the duration is hardly 5 months. The oysters reach marketable size in about one year's time and the average yield is good for the raft culture. The natural beds of clams along the west coast of India and in some parts of the east coast are rich and by simple transplantation method it would be possible to increase production.

Both inUSA and Japan industrial and domestic pollution, frequent occurrence of mass mortalities, recreational demand etc., act against the interest of molluscan culture and any substantial increase in production would become possible only through employment of high-cost advanced technologies. The developing countries, particularly those in the tropical belt, have very good prospects for the production of molluscs for meeting the protein and energy requirements of their people and also to meet the demands of the developed countries.

PRESENT STATUS OF MOLLUSCAN FISHERIES AND CULTURE IN INDIA

K. NAGAPPAN NAYAR

India has extensive molluscan resources along both the coasts, in the numerous islands, bays, backwaters and estuaries and also in the seas around the Sub-continent. A good quantity of mussels, oysters, pearl oysters, different species of clams, Trochus, Turbo, chanks and cephalopods are regularly fished throughout the year at various places. These have been exploited from time immemorial for food, pearls, and the shells for commercial purposes mainly for making curios and in the preparation of lime.

Out of the total fish landings of the world, reported by the F.A.O., the molluscan landings amount to only 5%. So far as the Indian Sub-continent is concerned the marine fish landing figures furnished by the CMFRI indicate a total of 1.4 million tonnes. Of this, the percentage of molluscan landings is meagre and comes only to about 1%. The picture that emerges would apparently indicate that molluscs are not very important for their fishery value which is contrary to fact. The reason for this anamoly is not far to seek; while the figures for the landings of commercially important species of cephalopods have been included, the actual landings of various species of clams, mussels, oysters, pearl oysters and heavy shelled forms such as chanks, Trochus and Turbo have not been estimated and included due to lack of precise data. In terms of weight landed, the above forms contribute substantially to the total landings and would give much higher figures of total landings of molluscs in India. Some of the above mentioned forms are fished not for the meat but for industrial utilisation. However, a proper assessment of the total landings of these forms appears essential.

The available literature on molluscan fisheries in India, past as well as recent publications, enables us not only to get a fairly comprehensive idea of the immensely rich resources of molluscs but also indicates the present status of the different molluscan fisheries. However, specific information in respect of many species is far from complete thus calling for a thorough coverage to give us upto-date details on the fishery, biology, population density and ecology of important species.

MOLLUSCAN FISHERIES

Mussels (Resources)

Mussels occur all along the coastal region, wherever rocky or submerged hard substrata are present. Two species of mussels are found along the Indian coast, the green mussel Perna viridis and brown mussel P. indica: whereas the former is found along the east and west coasts the latter is confined only to the southern part of the peninsular India. At present, regular exploitation of mussel is limited to certain regions like Goa - Karwar, Cannanore - Kozhikode, Varkala - Vizhinjam, and Colachel - Cape Comorin on the west coast and Chinna Muttom, Madras and Kakinada on the east coast. Green mussel P. viridis is reported from Gulf of Kutch and scattered beds are present from Ratnagiri to Mangalore. South of Cannanore upto Calicut this species is abundant. The Green mussel is found upto Varkala on the south west coast. In the east coast, green mussel is found at Porto Novo, Madras, Kakinada, Waltair and Sonapur, Brown mussel P. indica has a restricted distribution from Quilon in the south west coast up to Cape Comorin. Although there is a regular seasonal mussel fishery of considerable local importance along certain areas on the east and west coasts, it still remains an insignificant fishery of minor magnitude. Mussel flesh is popularly eaten, even considered a delicious item of food by the people of west coast. Since there is no authentic record of mussel-landings from various landing centres, it is difficult to give a correct estimate of the annual landings. It is, however, estimated that 20 tonnes are landed from Ratnagiri to South Kanara, 900 tonnes from Cannanore-Calicut area, 180 tonnes at Vizhinjam, 325 tonnes from Colachel - Cape Comorin and in the east coast about 2.4 and 7 tonnes from Madras and Kakinada respectively per annum which gives the total annual landings of mussels as 1435 tonnes.

Edible oysters

Edible oysters are found all along the coastal strips, estuaries and backwaters wherein suitable hard substrata are available for their young ones to settle down and grow. Oysters are collected from such natural beds by a good number of fishermen in the west coast, especially in the coastal regions of Karnataka and Maharashtra and sold in the local market. The edible oyster, C. madrasensis is a form which grows abundantly in a wild state forming extensive beds in the tidal creeks and backwater areas of the east coast. C. gryphoides and C. discoidea are mostly found in the northwestern coast of India. Nowhere in the east coast this valuable resource is commercially fished for edible purpose, except for a limited exploitation by the Tamil Nadu Fisheries Department arranging to collect a few thousand oysters every year from the wild stock at Pulicat lake and Ennore estuary for supply to a few western style hotels and for westerners in Madras. It has reported from Bombay (Rai, 1932) that oyster fishery was a regular feature during the twenties and more than 5000 persons were engaged in collecting oysters from the natural beds all along the erstwhile Bombay Presidency. Because of continued irrational and indiscriminate fishing by local fishermen the oyster pupulation was wiped out. The under-exploited oyster population in many estuarine regions of the east coast on the other hand are periodically subjected to large-scale destruction on account of freshwater admixture during N.E. monsoon. In the rest of the areas they settle down season after season forming thick and rugged bed formations and the individuals in the bed become so overcrowded and stunted and perish without being exploited.

Pearl oysters

The pearl oysters are the most thoroughly exploited for the pearls and mother of pearls from time immemorial. In the Indian region pearl oysters exist in the Gulf of Mannar and in the Gulf of Kutch and recently it has also been reported from Trivandrum coast. Six species of pearl oysters, are reported in the Indian coastal waters. Of these, P. fucata is the most important.

Clams

Among clams, those belonging to the family Veneridae are the most important found all along the Indian coasts in the bays, estuaries and backwaters. The important species which contribute to the fisheries are Meretrix spp., Paphia spp., Katelysia spp., Villorita spp., and Gafrarium sp. Among others Mesodesma glabratum (Lamarck), Solen kempi Preston, Sanguinolaria diphos (Gmelin) and Donax spp., are also found to occur in certain places all along our coast. The true cockles Cardium assimile Reeve and C. asiaticum Bruguiere, though occurring at several places, are not of much commercial importance. The ark-shell Anadara granosa (Linnaeus) which is referred to as cockle in some countries, forms a minor fishery in Kakinada. A detailed account on the clam cockle and oyster resources of the Indian coasts has been given by Alagarswami and Narasimham (1973). Meretrix meretrix is the main species which constitutes the fishery along the Maharashtra, Goa and North Kanara coast though it occurs all along the east and west coasts. Ranade (1964) has estimated that 3600 persons are engaged in the fishery and collect 24,03,000 pounds of clams annually valued at Rs. 2,88,000. In Goa it is estimated that more than 400 persons are engaged in clam fishery. In the Karwar region also the clam fishery is good and more than 450 persons are engaged in this fishery for the collection of M. meretrix and P. malabarica. Along the Kerala coast M. casta is found to occur in most of the estuaries and backwaters and forms a fishery but the magnitude of the same has not been estimated properly. On the east coast clam occurs in most of the estuaries and in addition to the live clam fishery at most of the centres there are certain places from where sub-fossil deposits are being regularly removed. In Ratnagiri area Solen kempi is being fished. Over 3 tonnes are fished annually. The window pane oyster Placenta placenta, known for its seed pearls it produces, has been under exploitation in the Gulf of Kutch where it occurs in abundance. In Kakinada more than 4000 tonnes of shells are fished annually which is valued at about Rs. 1,00,000/- Katelysia opima and K. marmorata are also fished in large quantities in Maharashtra State and in certain places the density of population is over $4,00,000/km^2$.

There exists a good fishery of Gafrarium tumidium in Palk Bay area and about 5 tonnes of clams are annually fished.

Donax sp. is also widely distributed along the sandy shores of Indian coast but there does not seem to be a well organised fishing for these clams.

The ribbed ark shell A. granosa is found in a few places. In Kakinada Bay a good fishery exists (Narasimham (1968)) and a total quantity of 1000 tonnes valued at Rs.50,000/- are fished annually and used in the manufacture of lime.

Chanks

Xancus pyrum, the common chank is abundant on the east coast of India from Cape Comorin to Madras although the density of its occurrence appears to thin out north of Point Calimere. On the west coast good number of chanks are fished from the Gulf of Kutch coast, but southward of this no chank is found till the southern coast line of Kerala State where it forms a small fishery. It is also found around Andaman islands to some extent. A detailed account of the chank fishery of India has been given by Nayar and Mahadevan (1975). On an average about 12,000 chanks are fished from Gujarat per annum.

From Kerala coast, about 17,000 chanks from trawl catches at Quilon, and from Vizhinjam area about 6,200 chanks by hooks and line are fished annually. In Colachel, Enayam and Kadayapatnam regular chank diving is being done and on an average land about 2,000 chanks annually. On the east coast Tuticorin is considered to be the best chank fishing ground from where over 1 mollion chanks were fished during 1978-79. More than 900 divers are engaged in this fishery at Tuticorin. Kannirajapuram to Tirupalakudi in the Palk Bay is also a very productive area and on an average 3,00,000 chanks are fished every year. From the other centres on the south-east coast such as Tanjore, South Arcot and Chingleput a total of 40,000 chanks are landed annually.

<u>Trochus and Turbo</u>

<u>Trochus niloticus</u> and <u>Turbo marmoratus</u> are the other commercially important gastropods fished all along the Andaman and Nicobar Islands for the past several years. Appukuttan (1977) has given an account about the <u>Trochus</u> and <u>Turbo</u> fishery in Andamans. It has been estimated that on an average 400 - 600 tonnes of <u>Trochus</u> and 100 - 500 tonnes of <u>Turbo</u> shells are fished annually from Andaman and Nicobar waters. <u>Trochus</u> shells fetch a price of Rs.4000/- per tonne whereas <u>Turbo</u> shells are sold not less than Rs.10,000/- per tonne. Shell craft industry is well established and a good number of artisans are regularly engaged in cleaning, polishing, cutting and carving these shells and various articles are made out of them. Of late the <u>Turbo</u> fishery is showing a decline perhaps due to over fishing. Apart from the detailed study made by Rao (1939) no other work seems to have been made in recent years. In 1978 two teams of Scientists of the CMFRI visited almost all the Andaman and Nicobar Islands during the period January - May to make general survey to find out suitable places for extending mariculture activities in and around the islands. During the survey the potentialities of the molluscan fisheries were also studied in detail. But a detailed study extending over a few years is absolutely essential to make a proper assessment of these commercially

important fisheries in and around the Andaman and Nicobar islands.

Cephalopods

Cephalopods comprising of squids, cuttle fishes and octopi are fished in appreciable quantities in India. 15,931 tonnes of cephalopods were landed during the year 1978 out of which 4,557 tonnes were from Maharashtra State, 6,516 tonnes from Kerala State, 1959 tonnes from Gujarat State, 1,346 tonnes from Karnataka State and 1,042 from Tamil Nadu. The important species are Sepia rouxii, S. aculeata, S. rostrata, Sepiella inermis, Seipioteuthis arctipinnis, Loligo duvauceli, L. hardwickii, Octopus rugusus, O. octopodia and O. favonia. The cephalopod catches are got incidentally only in shore-seines, boat seines and trawl nets operated for fin-fishes. The cephalopod resources of the offshore waters are practically not exploited. Studies conducted a decade ago (Silas, 1968) have shown that a number of species such as Symplectoteuthis oulaiensis, Sepia aculeata, S.pharaonis, Sepiella inermis and Loligo duvauceli are available in the offshore waters of west coast. Systematic exploratory fishing should be carried out on the continental shelf and beyond to locate new grounds in the Indian Ocean and in the Arabian Sea. The method of jigging used in other countries for fishing squids and cuttlefish should also be employed here to improve the cephalopod fishery.

MOLLUSCAN CULTURE IN INDIA

Molluscan culture is of very recent origin. Attempts have recently been made to culture mussels, edible oysters, pearl oysters, clams and also cephalopods by CMFRI.

Mussels

Investigations on the culture of the brown mussel (Perna indica) were carried out from the Research Centre at Vizhinjam from 1971 following the rope culture method using coir ropes for suspending ~~the~~ the mussels. The initial results were so encouraging that the work was extended to a few more centres such as Kozhikode, Madras and also Vizagapatnam, to find out the feasibility of culturing Perna viridis (green mussel). The open sea green mussel culture work at Kozhikode has given positive results.

Edible oysters

The importance of oyster culture was visualized as early as in 1910 by Hornell. He initiated oyster culture work on lines followed in France and established a farm at Pulicat, 40 km north of Madras city. The follow up programme was not carried out with the result, the progress was very much hampered. Similarly as early as in 1920's a good beginning was made by some of the fishermen of Bombay (Rai, 1928) to collect the young oysters and transfer them to suitable shallow regions in Mahim, on the Maharashtra coast where they allowed the oysters to grow to marketable size. Periodical monitoring and cleaning of the oysters were also carried out. Fairly large quantities of oysters were collected from all the available natural beds and sold in the market as there was great demand for them. These efforts were not backed by the Fisheries Department, or any other research organisation, with the result that the fishermen who did this work could not make much headway and improve their techniques, and they had to give up this line of work in due course. The need for utilization and augmentation of resource led the Central Marine Fisheries Research Institute to take up oyster culture work at Tuticorin in the year 1975. Various aspects of oyster culture such as spat collection from natural environments, hatchery development of seeds, growth of spat by following different techniques, control, purification of oysters, shucking and processing are being studied in a detailed way. Initial results obtained indicate a production of 150 tonnes of oysters per hectare. Some interested fishermen have taken up oyster culture.

Experiments on culture of clams such as Anadara sp., Villorita spp., are also being tried at present from Mangalore, Cochin, Kakinada and Waltair. The results are being watched. Attempts are also being made to collect the egg masses of squids and cuttlefish and rear them so that the initial mortality of the young ones by predators could be minimised to a very great extent.

Pearl oysters

The first attempt at culturing pearl oysters in captivity was made at Tuticorin as early as in 1864. A lot of work was carried out initially at Tuticorin and later on the culture work was shifted to Krusadai Island wherein it was continued for a number of years by the Tamil Nadu Fisheries Department. Attempts were also made in Gujarat to produce cultured pearls. But all these attempts did not yield results. In 1972 pearl culture work taken up by the Central Marine Fisheries Research Institute at Tuticorin at Veppalodai enabled production of perfectly spherical cultured pearls in the year 1973. Various other aspects of work such as production of oyster spat by hatchery method, improving the techniques of growing the oysters etc., are being pursued. Although pearl oyster beds have not been located at Vizhinjam area, a good settlement of young oysters had taken place during 1974 spat setting season. The young oysters thus collected were also grown to adult size oysters which promoted the Kerala Fisheries Department to take up pearl oyster culture on a pilot scale in 1978.

Farming or culture practice involving molluscs is ~~as~~ yet to be taken up on a commercial scale in India. Steps in this direction has been initiated to involve small-scale traditional fishermen. This is being followed ~~up~~ by a programme of financial assistance and loans under Integrated Rural Development Programme. It is envisaged that within the next decade India will figure as one of the important countries with established farms for oysters, mussels and clams.

TAXONOMY AND ECOLOGY OF CULTIVABLE MOLLUSCS

S. MAHADEVAN

The sorting of specimens into various species or sub-species and identifying them is known as taxonomy. The most comprehensive work on this subject has been brought out by Blackweldor (1967). While studying the taxonomy of molluscs one is bewildered by the amount of differences and variations even amongst two individuals belonging to same species. These may be attributed to very often, different age, sex, phases in a life cycle, positions in the colony, physical habitats, different colour due to different back grounds, mode of feeding or living on different hosts, parasitisation, and deformities or diseased condition etc. Therefore, amongst other things to identify and decide a species the taxonomist has to take careful note of the effects of above influences to avoid creating multiplicity of species. Of course, geneticists and evolutionists have other criteria to determine species. As yet there appears to be no satisfactory or accurate definition that encompass all concepts. The "biological species" concept a defined by Ernest Mayre (1942) is difficult to be used extensively in the field of molluscs for malacology is largely in the purely descriptive and cataloguing stages and the majority of the species described today are still based on the "morphological species" concept.

Every population of molluscs is inherently different and these differences, although minute, are morphological, physiological or genetic, whereas the ecotypes, observations and variations may not warrant even a sub-species creation.

It is sometimes possible to find natural populations in various stages of "becoming species". A hierarchy of successive levels of speciation can be found. These are populations which have almost reached species level still others that are full species; sometimes there are allopatric; in other cases the most distinct ones may be overlapping the ranges of their closest relatives. The responsible mechanism for these changes is geographic speciation or speciation by distance effecting the genotypic and phenotypic divergence or both.

This geographical variation together with isolation and cross-breeding might lead to an evolutionary production of species different from the type species. But this is a slow process taking several hundred years. To cite an instance, Hornell's revision of the Indian species of Meretrix collected from Orissa down to Cape Comorin and along West coast reveals a great diversity of morphological changes in the shell characters because of different environmental parameters and ecological set-up of the various localities in which the clams are found living. While distinct morphological as well as inter-breeding gaps exist between the aggregate of local population of the type species, the differences that are found are overlapping. This makes it difficult to generalise the field identification characters. A widely ranging species like Meretrix may also exhibit a clinal variation in one or more characters usually correlated with some environmental characteristic condition such as climate or latitude of the habitat. In fact a species may exhibit 2 or 3 clines, one going from north to south (climatic), the other east to west (latitudinal) or soil correlated.

Amongst the land, freshwater and marine species of molluscs, 80,000 described so far, well known edible forms throughout the world constitute but a very negligible percentage. In most countries of the world one or more such species are present and exploited from natural beds or by growing them in farms. The resources of edible molluscs along Indian coastal areas are very rich and varied. This offers vast scope for the development and expansion of culturing atleast a few important species. Table 1 not only presents a list of edible molluscan species present but also other species of potential, commercial and culture importance.

CHARACTERS USEFUL IN IDENTIFICATION OF SHELLS

While describing bivalve and gastropod shells several descriptive terms are used by Taxonomists. It is useful to know and understand the exact structures and features referred to in descriptive terminology. In order to avoid confusion and doubt regarding certain expressions commonly come across in shell descriptions the following glossary is given.

Dorsal and ventral sides

Dorsal side is located on the beak or hinge side. Opposite end of dorsal side is the ventral side.

Right and left valves

When a bivalve is placed on table on the ventral margin with dorsal hinge margin up (vertically) with the anterior end away from the observer the right valve is on the right side of the observer and the left valve to the left. Another quick way is to observe the concave interior of a valve with hinge margin away from observer and to locate the pallial sinus impression. If the sinus opens towards the left it is left valve and vice versa.

Dextral and Sinistral

To decide whether a gastropod shell is dextral or sinistral the opercular opening is kept facing the observer with the apex vertically up with the opercular canal resting on the table. If the opercular opening is on the right it is dextral; if it is on the left side it is sinistral.

Ligament: Chitinous region binding the two valves; ligament area in most shells are posterior to the beak.

Hinge: The region which hooks both valves together.

Teeth: The knobs or projections in the hinge interlocking the valves.

Adductor mussels	Muscles helpful in closing the valves
Adductor scar	Impression on the valves showing the position of adductor muscles of the live animal.
Umbo or beak	Apex of the shallow cone of each valve
Umbonal cavity	The interior cavity lying within the umbo
Prodisso-conch	The embryonic shell of the bivalve corresponding to the Protoconch of gastropods usually eroded away in adults.
Proso-gyrate	Term to denote the shells when the umbones curve in anterior direction.
Ophisth-ogyrate	If both umbo point inward towards the umbo of each valve.
<u>Lunule</u>:	Heart shaped impression insides, anterior to the beak
<u>Equivalve</u>:	Both shells of same nature
<u>Inequivalve</u>:	One valve larger or dissimilar
<u>Equilateral</u>:	Umbo is midway between anterior and posterior sides.
<u>Gape</u>:	When the valves do not fit closely together the opening in the margin.
<u>Resilum</u>:	The ligament proper and internal cartilage
<u>Pallial line</u>:	The fine single line impression produced by the muscular edge of the mantle.
<u>Pallial sinus</u>	"U" shaped notch on the posterior end of the valve indicating the posterior of a shiphon.

Amongst various molluscs of importance, oysters, pearl oysters, mussels, clams and cephalopods deserve our attention.

EDIBLE OYSTERS

Based on variations in shape, size and colour and texture of adult shell, structure of hinge plate of the larval shell and soft organs of the animal about 100 species of edible and inedible oysters were originally described. Ranson (1948, 1950) distinguished oyster genera mainly on the basis of larval shell structure.

The Ostreidae family as known today comprises of three genera *Ostrea*, *Crassostrea* and *Pycnodonte*. The last genus is considered as semifossilised or living in deep sea area. Of the other two, *Ostrea* spp., do not occur in Indian waters.

Amongst *Crassostrea* the following 17 species are well known.

- *C. angulata*
- *C. virginica*
- *C. gigas*
- *C. rivularis*
- *C. rhizhophorae*
- *C. iredalei*
- *C. commercialis*
- *C. glomerata*
- *C. madrasensis*
- *C. amasa*
- *C. echinata*
- *C. denselamellosa*
- *C. nippona*
- *C. margaritacea*
- *C. gryphoides*
- *C. discoidea*
- *C. tuberculata*

There are other species also like

- *C. folium*
- *C. quercina*
- *C. lacerata*
- *C. cuttackensis* (= *C. madrasensis* ?)
- *C. cristagalli*
- *C. cornucopia*
- *C. sikamea*

Of the above species, as already mentioned in Table 1, many species occur along the Indian coastal, bay and estuarine regions. Out of these only 4 are of any importance.

C. madrasensis

Brackishwater oyster occurs in estuaries, backwaters, at times in open sea. They are found in rocky or solid surface usually, but as in Ennore, Tuticorin and other areas on hard muddy bottom also.

C. gryphoides is mainly a backwater and estuarine species. C. cuculata occurs attached to sand stones, granite boulders, or corals in intertidal regions in brackishwater and estuarine regions. They are also found in open coast where rocks are encountered in the intertidal zones, while C. discoidea grows attached to rocks in deep-water of littoral zone.

MUSSELS

The family Mytilidae consists of several genera like Mytilus, Perna, Mytella, Adula, Semimytilus, Crenomytilus, Chromytilus, Septifer, Brachidontes, Hormomya, Aulacomya and Ischadium.

However, only species of Mytilus and Perna are of importance from the point of view of fishery and culture. The following species of Mytilus are of fishery value.

M. edulis (U.K, France)
M. galloprovincialis (Spain, Mediterranean)
M. californianus (Pacific coast. of U.S.A.)
M. smaragdinus (Philippines)
M. viridis (Malaysia, India) (See Perna viridis)
M. canaliculus (Newzealand)

Under the genus Perna, Perna perna (Brazil, Venezeula), P. viridis and P. indica (India) are important.

It has been shown by Kuriakose and Nair (1976) that the mussel species M. viridis occurring in India referred to as belonging to Mytilus genus is actually referable to the genus Perna. The brown mussel has been identified as a new species, P. indica. Mussels live in intertidal rocky areas and also in slightly deeper zones with hard substratum.

CLAMS

In other countries the important species are Mercenaria mercenaria (quahog clam or hard clam or little-neck clam) found in the

Atlantic coast of U.S.A, Virginia and Long island; Mya arenaria (soft clam or long-necked clam) found abundantly from Labrador to North Carolina, Tapes semidecussata (baby clam) T. japonica (Asari clam) found inJapan. The hard clam has been successfully introduced in Britain and France. Apart from the above Attrina japonica, Fulvia mutica, Mactra sachaliensis, M. sulcataria, Venerupis aurea, V. pallastra, V. rhomboides; Venus fasciata, V. striatula, V. verrucosa and Meretrix lusaria are the other clams whose flesh is eaten. The edible species found in India are listed in Table 1. Most of the Indian species fall under the family Veneridae, Donacidae and Solenidae, Satyamurti (1956) has given a detailed statement of the characters of different genera of Veneridae which include Gafrarium, Katelysia, Meretrix and Paphia.

1. Meretrix

Meretrix species live mostly within the influence of land drainage. They are euryhaline. In M. meretrix we come across divergent characters of shell, those of east coast being usually true to type within narrow limits. In west coast, even when living within the same estuary it exhibits as many as three well marked variations connected by intermediary forms merging into one another making it difficult to allocate many to one particular group. Meretrix casta is found in river mouths and Meretrix casta var ovum is generally abundant in west coast backwaters growing to a size of 35.40 mm.

2. Katelysia species

Katelysia opima and K. marmorata are the important species. In K.opima the shell is thick, inflated, smooth and yellowish brown. Inner surface is white, pallial line deeply sinuate; resembles M. casta but differentiated by deeper colouration rayed with number of concentric undulating lines parallel to 3 or 4 purplish markings; anterior tooth of left valve absent and corresponding cavity in the right valve is also absent. Lunule distinct; area behind umbone well defined;

flattened and elongated reaching almost upto the hind margin. Muscular impression well marked.

This clam inhabits estuaries; backwaters; it prefers water edge near river mouth; very rare in low salinities.

3. Paphia species

Elongate shell, concentrically sculptured with a narrow lunule; hinge area short; pallial sinus deep. The distinguishing features of the two important species are:

Surface of shell smooth and polished; pale yellowish while marked with pale purplish grey arrow head markings " " shell elongate with anterior and posterior margins rounded.	P. textile
Concentric grooves, strong throughout the shell surface. Front and hind margin narrowly rounded; ventral margin slightly indented towards hind end; pale yellowish brown colour indistinctly rayed with grey brown bands	P. malabarica

In addition to the above Paphia laterisulca also appears to be an important species. The above species inhabit river mouths where the bottom is sandy mud.

4. Donax species

Shell trangular, elongate, inequilateral, stouter posterior side; surface smooth and scultpured. Pallial sinus deep and rounded. The characters of the important species have been given by Satyamurti (1956).

Razor clams

Elongated bivalve shells; Solen truncatus, S. lamarck. S. linearis, S. asperus, S. aquae dulcioris and S. kempi are the common species in India. Of these S. kempi appears to be of commercial fishery value. The diagnostic characters of various species have been furnished by Rao et al (1972). Razor clams inhabit intertidal mud flats.

OTHER BIVALVES

Anadara granosa is the most important of the cockles cultured in countries like China, Philippines, Thailand, Borneo and Malaysia. The term cockle has no taxonomic significance.

In India extensive beds of A. granosa are found at Kakinada in the east coast. Elsewhere they are present but not of commercial value.

Gafrarium tumidum, Mesodesma glabratum and Sanguinolaria diphos are not dealt with here because of their comparative insignificance with regard to culture at present.

PEARL OYSTERS

Pearl oysters belong to the genus Pinctada under the family Pteriidae. Members of this genus have long and straight hinge; long axis of shell at right angle to hinge; left valve deeper than right; byssal notch on each valve anteriorily.

In Indian waters P. fucata is the most abundant species but the occurrence of P. margaritifera, P. chemnitzi, P. atropupurea, P. anomioides and P. sugillata is not uncommon.

The field identification characters of these species have been given by Rao (1974).

CHANK

Chanks inhabit only sea beds where the bottom is fine sandy. At time they are seen adjacent to the rocky beds also on coarse sand. They prefer waters of depth beyond 10 metres.

Key to identification of the five varieties Indian chank, Xancus pyrum.

A. Spine elongate; shell fusiform; breadth in length 1.75 to 2	Shoulder angular prominent	var. fusus (Andamans only)
	Shoulder rounded and low	---- 1
1(a) Profile of whorls in spine convex		var. acuta
(b) Profile of whorls in spine straight		var. comorinensis
B. Spine short; shell either globular or top shaped; breadth in length under 1.75		--- 2
2(a) Spine moderately short; shall globose; periostracum rough and thick		var. globosa
(b) Spine often very short shell top shaped very wide at shoulder, periastracum thin and often sculptured in small shells.		var. obtusa

CEPHALOPODS

The cephalopods (squids, cuttlefish and octopi) are exclusively marine molluscs. Several species have reported but to mention a few of the commonly occuring cephalopods are Sepia pharaonis Ehrenberg, S. aculeata Ferussac & d'Orbigny, S. thurstoni Adam & Rees, S. brevimana Steenstrup and Sepiella inermis (Ferussac & d'Orbigny) among cuttlefish, Sepioteuthis arctipinnis Gould, Loligo hardwickii, Loliolus investigatoris Goodrish and Euprymna stenodactyla Grant among squids and Octopus dollfusi Robson, O. rugosus (Bosc), O. globosus Appellof, O. herdmani Holye and O. hongkongensis Hoyle among octopi (Rao, 1958; Silas, 1968).

Key to the field identification of the different genera of cephalopods to which the common species belong has been given by Sarvesan (1974).

Squids

Squids belong to the order Teuthoidea (Decapoda) which includes the majority of cephalopods, possessing a streamlined soft body with a pair of fins varying in shape, size and disposition. The distinct head in front is with ten circumoral arms provided with toothed suckers or claws or both. An internal shell known as pen or gladius, when present is imbedded in the dorsal mantle skin. The gladius of squids is almost transparent, thin and chitinous in nature. It varies in shape in different species.

Cuttlefish

Cuttlefishes belong to the order Sepioidea. Like squids, they possess well-defined head and ten arms. They have a broad and flattened body with narrow fins running along the sides to the full length of the body. The arms are comparatively short and provided with subequal suckers mostly arranged in four transverse rows. The two long slender tentacles are retractile into special pockets and used at the time of capturing the prey. The characteristic internal shell or the cuttlebone is calcified and differs in shape and size in different species.

Octopi

Octopi belonging to the order Octopoda, possess a short rounded body and a distinct head fringed with eight arms, which are provided with a broad enterbranchial membrane. The saccular mantle lacks fins. The suckers, arranged in two rows, are without stalks and horny rings.

TABLE - 1

1. Group	Edible Scientific name	Commercial or industrial Scientific name	Distribution
Oysters	*Crassostrea madrasensis* Preston (Madras Oyster)		Sonapur, Godavari delta, Gokulapalli, Pulicat, Ennur, Madras, Cuddalore, Athan-rai, Tuticorin, Kerala Coast
	2. *C. cucullata* (Barn) (Rock Oyster)		All over India
	3. *C. gryphoides* (Schlothum) (West coast oyster)		Kutch to Karwar
	4. *C. discoidea* (Gould) (West coast oyster)		North Kanara - Kutch, Dwaraka, Bombay, Ratnagiri, Jaytapur.
		5. *Crassostrea cristagalli* (Linn)	Tanjore coast, Palk Bay, Gulf of Mannar
		6. *C. folium* (Gmelin)	Kutch, Pamban
		7. *C. cornucopia* (Chemnitz)	Marmagoa
		8. *C. glomerata* (Gould)	Kutch
		9. *C. belcheri* (Sowedy)	Karachi
		10. *C. quercina* (Soweby)	Karcahi
		11. *C. cuttackensis*	Orissa

1	2	3	4
		Pinctada fucata (Gould) (Indian pearl oyster)	Gulf of Mannar, West coast
		2. *P. chemnitzii* (Philippi)	Palk Bay, Orissa coast, Tuticorin
		3. *P. sugillata* (Reeve) (flat oyster)	Tuticorin, Vizhingam, Madras
		4. *P. anomioides* (Reeve) (flat oyster)	Bombay, Madras, Palk Bay, Tuticorin, Vizhinjam
		5. *P. atropurpurea* (Dunker) (flat oyster)	Madras, Tuticorin, Palk Bay
		6. *P. margaritifera* (Linnaeus) (Blak lip)	Indo-pacific
		7. *Placenta placenta* (Window-pane oyster)	Kutch, Kakinada, Orissa, Thana creek, Bombay, Adyar, Pulicat, Chilka, Vellar, Courtalayar, Tellicherry, Malabar coast, South Kanara.
2. Clams	*Meretrix meretrix* (Linnaeus)		Bhatya creek, Kalbadevi creek, Myna Bay, Mahaluxmi creek, Mahim creek, Alibagh, Ratnagiri, Kali river, Kodibag, Ankola, Tadri (Agnahasini river) Moorba, Wadgoni. Mirojan, Wadgoni, Mirojan, Harwada, Mudgian, Sanikatta, Adyar, Courtalayar, Vellar, Cooum, Pulicat, Chilka, Tellicherry, (Malabar coast)
	M. casta (Chemnitz)		Pulicat, Adyar, Vellar, Ennore, Pinnakayal, Athankarai
	M. casta var *ovum* (Hanley)		Kerala coast

1	2	3	4
	Villorita cyprinoides (Gray)		West coast estuaries and backwaters
	V. cyprinoides var cochinensis		Cochin backwaters
	Katelysia opima (Gmelin)		Adyar, Vellar, all important South Indian estuaries and backwaters.
	Paphia malabarica		Karwar and north Kanara river mouths
	P. textile		Karwar and north Kanara river mouths
	P. marmorata		Karwar and north Kanara river mouths
	Donax cuneatus (Linneaus) (Wedge clam)		East coast, Palk Bay, Gulf of Mannar
	D. incarnatus (Wedge clam)		Palk Bay, Gulf of Mannar, East coast
	Gafrarium tumidum (Roding)		Gulf of Mannar, North Coromandal coast, Gulf of Mannar islands
	Mesodesma glabratum (Lamarck)		North Caromandal coast, Gulf of Mannar, West coast.
	Solen kempi Preston (Razor clam)		Ratnagiri coast
	S. lamarcki (Razor clam)		Gulf of Mannar
		Tridacna maxima Roding (Giant clam)	Andamans & Nicobar, Lakshadeep
Cockle	Anadara granosa (Linneaus) (Blood cockle)		Kakinada, Coramandal coast

1	2	3	4
Mussel	Perna viridis linnaeus (Green mussel)		East coast and west coast
P.	P. indica Kuriakose & Nair (Brown mussel)		Quilon, Kanyakumari, Vizhinjam, Trivandrum, Periathalai, Colachel, Muttom, Kovalam
Squids, Cuttle fishes, Octopi	Sepioteuthis arctipinnis (Gould) (Palk Bay squid)		South east coast of India
	Loligo duvauceli d' orbigny		East and west coast
	Sepia pharaonis Ehrenberg		Indian coast
	S. aculeata Ferussac & d' Orbigny		Indian coast
	Sepiella inermis (F & O)		East coast, Indian ocean
	Octopus herdmani Hoyle		Palk Bay
	O. dollfusi		Gulf of Mannar
Chanks		Xancus pyrum var acuta (Sacred chank)	Gulf of Mannar
		X. pyrum var obtusa "	Palk Bay and Coramandal coast
		X. pyrum var comorineses "	Kanyakumari coast
		X. pyrum var globosa "	Trivandrum coast
		X. pyrum var fuses "	Andamans

FISHERY AND BIOLOGY OF EDIBLE OYSTERS

S. MAHADEVAN

FISHERY

In India four species of oysters are recognised as important from the point of view of edibility of meat. But there is no large-scale fishery as such for any of the four species. However, at Pulicat and Ennore sporadic exploitation of *C. madrasensis* is reported. The oysters so removed is sold to Madras hoteliers. In many areas live beds of oysters are destroyed by local agents for utilizing the shells so gathered for lime shell industry (e.g. in Bahuda river estuary, Vaigai estuary at Attankarai, Vembanad lake, Kali river estuary). In the case of *C. gryphoides* small-scale exploitation of this species has been reported from North Kanara to Kutch. The season of fishing is from October - May. The fisherfolk, mostly divers, use an axe (called "Koodal") to detatch the oysters from rocks. Satpati, Palghar, Navapur, Kalve of Bombay coast, Alibaug, Jaytapur, Malwan, Karwar and Honavar, south of Bombay are some of the places where the exploitation goes on. In some places fishermen do try on-bottom transplantation of oyster seeds which when fully grown to marketable size are harvested and sold at a rupee for a dozen oysters. *C. cucullata* is also fished by removing the firmly attached oysters with the help of a strong knife or pick-axe. These oysters are collected in a bomboo netted hand dredge. The oysters are shucked and the flesh is put in seawater containers prior to selling. Very little information is available about *C. discoidea*.

From the above it may be seen that only a fringe of the population of oysters growing in the wild state is being exploited and for edible purposes. The shell lime industry is supported by a few hundred tonnes of oyster shells collected either by mops or by mining or quarrying in estuarine beds. There is considerable scope for better utilization of natural stock by resorting to intense fishing.

BIOLOGY

Very little work has been done on the biology of C. cucullata and C. discoidea. Therefore our information is mostly confined to C. madrasensis and to a lesser extent to C. gryphoides.

C. madrasensis

Rate of growth in Natural beds: It is interest to note that hermaphroditism occurs in this species in all seasons. Premonsoon and post monsoon changes from male to female and vice versa respectively has has been observed amongst the oyster stock at Attankarai.

Gonadial maturity: It is reported that oysters at Madras have a continuous breeding habit although in Adyar estuary it was found that there were two spawning maxima, one in April - May and the other in September-October. A similar gametogenetic activity was observed at Ennore also, although cases of oysters with ripe gonad throughout the year were not unusual. An identical pattern of breeding has been observed at Attankarai estuary and Tuticorin creeks also. Loosanoff (1942) has drawn our attention to the correlation between gonadial activity of oyster and water temperature.

Spawning: It appears that the oyster spawns twice a year once in April - May and again in September - October of each year. There appears to be some relationship between spawning and changes in salinity of seawater. Lowering of salinity is said to stimulate spawning. Salinity range of 22 - 25‰ and low temperature range 24 - 25°C in the estuarine regions appear to be quite favourable for spawning. At Tuticorin however the period of high salinity and high temperature during April - May coincides with the ripening of gonads resulting in a spawning peak.

Early development: Complete studies on the larval development of the species upto the spatfall stage are lacking. However we have definite information regarding the early development of C. madrasensis through the publication of Moses (1928), Devanesan and Chacko (1955). According to Samuel (unpublished) the mature females contain spherical ripe eggs measuring 49 μ - 59 μ in diameter. The gastrula stage is reached in 6 hrs. followed by trochophore stage lasting upto 13 hrs. At the end of 24 hrs, straight-hinge stage is reached. At this stage it measures 64 μ x 49 μ with a general pinkish orange colouration. It takes 11 days more for metamorphosis at the end of which the larva settles down as spat.

Observations made on oysters sampled from beds at Madras and Ennore by Paul (1742), Rao and Nayar (1956) reveal that at the most they grow to 54 mm in 150 days and reach 63 mm in one year and four months. Growth is faster in the first four months and the rate slakens as the oysters become older. In certain periods of the year when growth is retarded distinct zonations of interrupted lines denoting the arrested period are also reported to occur.

Studies on the growth rate of oysters under farm conditions at Tuticorin reveal that the average growth rate is 10 mm per month for the first three month which slows down to 8.3 mm in the next five months. Later growth rate has been observed to become progressively less. Majority of oysters reach a size of not less than 90 mm in 12 month period.

Spat fall: Since the larval development is external the fertilized eggs are subjected to dispersal depending on the prevalent currents and tidal amplitude. This is one of the restricting factors in cent per cent spat fall in the area of the oyster bed. The other vicissitude is the plankton feeding fishes which might feed on the eddgs and larvae. The third factor is how ideal is the substratum in the estuarine region or sea at the time of spatfall. Each female oyster is known to release a few millions of ripe ova which get fertilised and after overcoming these natural adverse conditions only a fraction of the fertilized lot might settle down as spat and survive.

The sheltered bays and backwater areas where the intensity of current is very feeble appear to be ideal surrounding for settlement.

Food: Not much work has been done in this regard. Diatoms constitute the main food. The stomach contents consist of Biddulphia, Rhizosolenia, Chaetoceros, Coscinodiscus, Pleurosigma, Navicula, Dinophysis, sponge spicules and unrecongnisable plant detritus.

Parasites, predators and pests: The shell boring polychaete Polydora ciliata and Polydora armata cause damage to shells with the result that the meat quality becomes poor. It appears that such parasitised shells can be treated by immersing them in freshwater for 16 hrs. or for 3 hrs in ½% solution of the ammonia salt of dinitro-orthocresol which kills the worms. Fouling organisms like barnacles, other molluscs, polyzoans, tunicates and algae are considered mainly a nuisance. Starfishes and drills are not known to play havoc in Indian waters where the oyster beds exist. Crabs like Scylla serrata and Thalamita crenata feed on oysters during the spat stage but not considered as serious pests. Mass mortality of oysters due to anoxic conditions are however not unknown. The greatest danger to oyster life is the admixture of freshwater in the estuarine regions during monsoon rains, causing salinity drop beneath tolerance level. Similarly in severe summer where river mouths close due to sand bar formation oysters living in shallow impoundments die due to abnormal rise in salinity caused by solar evaporation.

Quality of meat and percentage edibility: The percentage edibility is low after oyster spawning i.e May - July and again in November - January. This differs from one area to another depending on the spawning habit of the oyster in that locality. The average maximum percentage edibility at Mandapam area is known to be 6.86 and at Tuticorin 10 .5.

Chemical composition: Not much data are available on the quantitative analysis of chemical composition of the flesh of oysters in different environmental conditions.

Fat accumulation is known to go upto 2.7%(wet weight) whereas the protein content varies from 5.7% to 13.3%.

C. gryphoides

Rate of growth: The oyster spat in the natural beds in Kelwa backwaters are known to be very slow not exceeding 3.5 mm per month. The maximum growth observed in 6 months is 37 mm and at the end of 12 months a growth of 48 mm has been recorded. It has been opined that the salinity of the area in which these species live considerably influences the growth.

Food: Diatoms (belonging to 20 genera) and detritus have been recorded from the stomachs of oysters growing in Bombay coast. Intense feeding activity has been recorded from October to December.

Gonadial maturity & spawning: The species is said to spawn in July - September and spat fall begins in July. The animal becomes fatty and cream coloured from November to June indicating the maturing gonads and intense feeding activity prior to spawning.

Percentage edibility: The values are high from January to June and low during July-September. It is said that the fall in percentage edibility of females during spawning is quicker than in males.

Chemical composition: The fat content varies from 0.48 to 3.20%. (wet weight). The protein content shows a range of 2.79 - 9.89%. The calcium and phosphorous values are higher in the spawning period.

Parasites: Pinnotheres has been observed to infest this species; possibly depriving and interfering with the normal food supply. No further details are available about other pests, competitors and cases of mass mortality.

FISHERY AND BIOLOGY OF MUSSELS

P.S. KURIAKOSE

Two species of mussels occur in India, the green mussel, Perna viridis and the brown mussel, Perna indica.

The green mussel fishery is important in Malabar coast. This mussel locally known as "Kallummelkai" (Rock fruit) or "Kadukkai" is eaten by the poorer section of the population. Since last two decades it has become a preferred delicacy even among the upper class people. Recently some factories are engaged in canning and freezing mussel meat for internal and export market.

FISHERY

The important mussel fishing centres in the Malabar area are Kasaragod, Cannanore, Dharmadom, Thalai, Mahe, Chombala, Badagara, Thikkodi, Cadaloor, Kollam, Moodadi, Kappad, Elathur, Puthiappa, Calicut, Chalium and Beypore. In these areas there are extensive mussel beds extending in an area of 2 to 3 kilometres from coast. About 800 people are regularly engaged in the fishery from Cannanore to Beypore. When the beds are exposed during low tide women and children collect large numbers of mussels by hand. The important fishing method is collection of mussels by diving. Two or three divers go in a canoe to the submerged rocks away from the shore and dive to collect the mussels from the rocks. These mussels are stored in a coir net bag tied to their waist. Diving goes on till sufficient quantity is collected. Often a single person goes for this type of fishing on a floating log locally known as "Mutti". He suspends a big coir bag called "Mal" from the mutti for storing his collection. The method of collection is the same as above. When the bag tied to the mutti gets filled up, he comes ashore, unloads his catch and goes again for fishing on the same day depending on the market demand.

The important factor in the mussel fishery is that the mussels are sold in live condition. The catch is sold to the merchants in the landing place itself. Formerly the mussels were reaching the market and consumers by head load only but recently trucks are engaged for transporting to internal markets also. Mussel meat alone neatly packed in plastic bags is available in the market. No reliable statistics are available regarding the mussel production in India. On a rough estimate the annual mussel production may amount to 15,00 tonnes.

BIOLOGY

Food: Microscopic algae and diatoms constitute the food of mussels. Large quantities of detritus also form the food of mussels.

Growth: Spat settlement along the Indian coasts takes place during the months of August, September and October. Thick carpet like growth of young mussels can be seen all over the inter tidal and submerged rocks during this period. It takes twelve months to attain the harvestable size in natural beds. Due to overcrowding of mussels, population the growth is comparatively slow. Moreover some of the beds are subjected to tidal exposure and constant surf action. This is also a limiting factor. It is observed that early growth is rapid. During the first year the mussel attains a length of 77 mm and in the next 6 months it grows to 97 mm. The mussel attains a length of 110 mm in 2 years.

Spawning: The sexes are separate. The gonad maturity commences in May and fully ripe condition is reached during June. Along the Indian coasts mussels spawn from July to October with a peak spawning period in August and September. The female are known to release up to 10 million eggs in a single spawning. The males simultaneously release their spawn and fertilization takes place in sea water.

After fertilization the developmental stages are extremely rapid. The trochophore stage is reached in about 12 to 14 hours and and the 'D' shaped larva or the early straight hinge larval stage is reached within three days, the hinged veliger stage on the 7th day while the late veliger is reached on the 10 th day of development. The larva prefers rough surface to smooth ones for settlement.

FISHERY AND BIOLOGY OF CLAMS AND COCKLES

K.A. NARASIMHAM

a) Meretrix meretrix (Linnaeus)

Exploitation and fishery: Rai (1932) estimated the production of this species and *Katelysia opima* in the erstwhile Bombay Presidency approximately at 8818 tonnes. Ranade (1964) stated that from Thana to Ratnagiri District about 3708 tonnes of the above two species are landed annually from 34 creeks. The most productive areas are the Kalbadevi estuary and Bhatia creek in Ratnagiri District. Tarkarli creek south of Malwan is also important. Clams are collected by men, women and children at low tide by hand picking. Canoes and rake nets are also used. Women market the clams at Bombay, Ratnagiri and Malwan and the last two places are important market centres for *M. meretrix* (Alagarswami and Narasimham, 1973).

In Goa, Tiracol, Chapora, Sal, Mandovi and Zuari rivers are important for clams in that order. This species is mainly fished at Siridao, Siolim and Ribander. About 400 to 500 persons are engaged in clam digging in Goa and fishing is throughout year except the monsoon (Alagarswami and Narasimham, 1973. Panaji and Mapura are important marketing centres.

In the North Kanara District Kalinadi estuary has rich clam beds of *M. meretrix*. Important clam fishing villages along the estuary are Kodibagh, Nandangadda, Sunkeri, Sadasivgarh and Kanasgiri. The above species is dominant on the bank side of the estuary. Here 300 to 400 persons are engaged in clam fishing and 50 canoes are deployed for the purpose. A clam net locally known as "Akhya" is used. The annual output of clams from Kalinadi is about 1000 tonnes of which about 50% is by *M. meretrix* (Alagarswami and Narasimham, 1973). Other important centres for this species along the North Kanara coast are Ankola, Moorba, Wadgoni creek, Mirjan, Horwada, Mudgian, Sanikatta, Tadri and Aghanasini. Here clams are fished throughout the year with a peak in March-June. Sanikatta and Ankola are important marketing centres for clams. In the extensive clam beds of the Sharawathi estuary *M. meretrix* is the dominant species. On both sides of the estury about 100 persons regularly collect the clams.

In Tamil Nadu it is fished on a small-scale in the estuaries of Adyar, Courtalayar, Vellar and Cooum (Nayar and Mahadevan 1974). In the Kakinada Bay about 400 tonnes of this species are collected annually (Narasimham, 1973). It is also found in Pulicat lake and Chilka Lake.

Present status of utility: The flesh of the clams is tasty before they spawn and at this stage they are exploited indiscriminately (Nayar and Mahadevan, 1974). Apart from their use as food the shells are used in lime making at several places like Kodibagh, Sadasivagarh, Sunkeri and Nandwad.

Biology: Rai (1932) reported that the principal breeding season of M. meretrix on the Bombay coast lasts from March to June and under favourable conditions it may continue year round except during monsoon. On the east coast this clam spawns about the beginning of September and again in May (Hornell 1922). M. meretrix can withstand low salinity of 10.5% under laboratory conditions when the change is effected suddenly. On acclimatization to low salinity it can stand 5.0%. salinity (Ranade and Kulkarni 1973) and this helps the clams to survive the low salinities prevalent during the monsoon.

b) Meretrix casta (Chemnitz)

Exploitation and fishery: In South Kanara this species is important in Coondapur, Silanadi, Malpe, Mulki, Gurpur and Netravati rivers (Alagarswami and Narasimham, 1973). In the Mulki river canoes are employed to transport the women divers to pick the clams which are emptied into 'madi' (a piece of cloth folded like a bag) or in a bag net fastened to their waists. The clams are marketed at Malpe, Mangalore and Mulki.

Along the Kerala coast M. casta is one of the important clams in most of the estuaries and backwaters. At Kozhikode, Beypore, Vembanad lake and Quilon this species is fished for local consumption.

In the east coast M. casta beds occur in the estuaries of Athankarai, Pinnakayal, Vaigai, Vellar, Adyar, Cooum and Ennore backwaters. The species is known to exist at Pulicat lake and Chilka lake also. In the Adyar estuary, Ennore estuary and Pulicat lake each woman collects 300-400 clams a day and on thickly pupulated beds 2000-3000 clams may be picked up and taken home in baskets (Nayar and Mahadevan, 1974). The clams are not regularly sold in the markets and they are traded by barter system for commodities like paddy, sweets or pulses.

Utility: At Ullal near Mangalore over 3000 tonnes of lime is produced valued over Rs. 5,00,000. The lime is used in manuring coffee plantations (Alagarswami and Narasimham, 1973).

Growth: In the Adyar estuary it grows to a length of 48.7 mm in about 18 months. Growth is retarded twice in a year (Abraham, 1953). It attains a size of 56.3 mm in about 3 years but nearly 90% of clams are fished before they reach 30 mm length. An average growth of 2.9 mm/month was reported by Harkantra (1975) from the Kali estuary during the first year and 2.7 mm/month by Parulekar et al (1973) from Goa. Dimensional relationships in this species were studied by Durve and Dharmaraja (1965) and Parulekar et al (1973). Durve (1975) observed change in the form of the shell during growth and suggested that it is essentially genotypic.

Condition factor: The percentage edibility (ratio of meat weight to the whole weight) of M. casta of Ennore backwaters varied from 7.62 to 15.75 (Venkataraman and Chari, 1951), and at Goa it ranged from 11.26 to 12.08 (Krishna Kumari et al., 1977).

Bio-chemical composition: The protein varied from 7.98 to 12.21%, fat 0.63 to 1.1% (Venkataraman and Chari, 1951). Their data show that the clams are rich in protein and minerals. The caloric value of M. casta was estimated as 3369 cal/g dry wt. (Sumitra Vijayaraghavan et al., 1975). Gopalakrishnan et al., (1977) observed a high protein content of 18.5% and gave the caloric value at 4755 cal/g.

<u>Maturity</u>: This species is reported to attain sexual maturity at 11 mm length and when one month old by Abraham (1953) and at 10-25 mm length by Harkantra (1975).

<u>Spawning</u>: In the Adyar estuary <u>M. casta</u> spawns throughout the year with peak activity in July-August, October-November and March-April (Abraham, 1953). Hornell (1922) stated that this species spawns twice in a year during April-May and in September. Durve (1964) recorded continuous spawning except for a break in late summer which related to hypersaline conditions in the marine fish farm at Mandapam. At Goa, continuous spawning throughout the year with a slight peak in March-April was observed by Krishna Kumari <u>et al</u>.,(1977). Parulekar <u>et al</u>., (1973) also stated that this species at Banastrim near Goa spawns throughout the year. Harkantra (1975) reported that it breeds throughout the year in the Kali estuary with a possible break in the winter.

<u>Parasites</u>: Silas and Alagarswami (1967) and Harkantra (1975) recorded the pea-crab <u>Pinnotheres</u> sp. in <u>M. casta</u>. They damage the gills, mantle, digestive gland and gonad. Durve (1964) observed that a few <u>M. casta</u> were parasitized by bucephalid cercaria.

c) <u>Villorita cyprinoides</u> (Gray)

The black clam is small and thick walled contributing to the clam fisheries along west coast. This species cannot withstand high salinities.

<u>Exploitation and fishery</u>: In Goa it is fished at Siridao, Savoi, Amonen and Naibag. In the Mangalore area also this species is fished and sold. Along the Kerala backwaters it is available in the Cochin area and at several places to its south (Alagarswami and Narasimham, 1973).

<u>Utility</u>: Apart from its value as food the shells are used in the cement manufacture. The Travancore Cements Ltd., Kottayam dredge annually about 60,000 tonnes of shells valued at Rs. 10,80,000 from the subfossil

deposits of the Vembanad lake. About 10,000 tonnes of white cement and 40,000 tonnes of grey cement are manufactured from these shells (Alagarswami and Narasimham, 19 73). Nothing is known of the biology of the species.

d) Katelysia opima (Gmelin)

This species is of considerable importance in Maharashtra State.

Exploitation and fishery: This species accounts for half of clam production in the Ratnagiri District. It is extensively fished at the Kalbadevi creek near Ratnagiri and Tarkarli creek near Malwan. It is next in importance to M. casta on the east coast, especially at Adyar (Nayar and Mahadevan, 1974). It is never found in the interior of backwaters where the salinity is low.

Utility: They are generally eaten by poorer classes people and the shell is used in the preparation of lime.

Growth: According to Rao (1951) the life span is 3 years and clams of the size 26-33.8 mm in length are over one year old. Similarly 38.8 to 43.5 mm length are two year old clams. Growth is arrested during August-December period when there is a fall in salinity.

In the Kalbadevi estuary it attains a length of 22 mm, 31 mm and 43 mm by the end of 1,2 and 3rd year respectively (Mane, 1974a). The growth rate is not uniform throughout the year and it is rapid from September to January, moderate from February to May and poor during June-September. The retarded growth during the monsoon is correlated with low salinity and the disturbance rings formed at this time were made use in age determination (Mane, 1974a).

Maturity: In the Adyar estuary first indication of sexual maturity is observed in 11-12 mm clams when they are 3 months old (Rao 1951). In Kalbadevi it attains sexual maturity at a size of 12 mm in males and 13 mm in females (Mane, 1974 a).

Spawning: Spawning begins in December in the Adyar estuary when the river is in communication with the sea and lasts about a month (Rao 1951). In the Kalbadevi estuary the clams spawns twice a year; major spawning takes place in October-November and a minor one confined to March-April period (Mane 1975). The spawning in October is attributed to salinity and temperature rise.

Physiology: Ranade and Kulkarni (1973) stated that K. opima tolerates a low salinity of 14.0%.. under laboratory conditions when the transfer to low salinity is sudden. On acclimatization to low salinity its tolerance limit comes down to 7.5%. Comparable results on salinity tolerance were obtained by Mane (1974b). Thus acclimatisation has survival value during monsoon when the estuarine salinity ties are low.

e) Paphia spp.

Paphia malabarica, P. laterisulca, P. textile and P. marmorata are the common species exploited along the Maharashtra, Goa and North Kanara coasts. Paphia occurs along the Malabar coast and east coast of India but not in abundance.

Exploitation and fishery: P. laterisulca occurs in Mahim Bay and is found in most of the estuaries along the Maharashtra coast. In Ratnagiri District about 10% of the clam production is accounted by Paphia. In Goa it occurs in Siolim, Siridao and Ribander. Near Karwar in Kalinadi P. malabarica is abundant (Alagarswami and Narasimham 1973). It occurs in depths upto 4 metres in sandy mud. During low tide fishermen take small scoop nets in one hand against the current and the clams are pushed into the net with the other hand. They are fished throughout the year with a peak between January and July. During peak fishing each individual collects 40 kg per day and about a tonne are landed daily in each centre (Nayar and Mahadevan, 1974).

Biology of P. laterisulca: Mane (1979) studied its biology from the Kalbadevi estuary. The clam grows to a length of 23, 38, 47 and 50 mm at the end of 1,2,3 and 3.5 years respectively. The retardation of growth in the monsoon is attributed to low salinity and monsoon checks in the form of annual rings are formed. These were also used in age determination. Sexual maturity is attained at 16-18 mm, spawning takes place from September to March with 2 peaks in November and March.

f) Donax spp.

Donax spp. are called wedge clams or bean clams and are widely distributed along the exposed sandy shores of our coast line.

Exploitation and fishery: D. incarnatus Gmelin is common along the Bombay coast, Goa, a number of Bays around Karwar and Cochin. D. cuneatus Linnaeus and D. faba Gmelin are widely distributed both along the east and west coasts. D. scortum Linnaeus is fairly abundant along the Palk Bay and Gulf of Mannar (Alagarswami and Narasimham, 1973). Though they are abundant, at present there is no regular fishery for these clams as food or any organised lime making industry with the result the resource is neglected (Nayar and Mahadevan, 1974).

Biology of D. cuneatus: •At Palk Bay it grows to a size of 13-14 mm in 11 months. The life span is two years and it grows upto 19 mm. Ring formation due to cessation of growth in November-December was observed (Nayar 1955). At Ratnagiri it grows to a size of 13-14 mm, 21-22 and 22 to 23 mm within 1,2 and 2.5 years respectively. Growth was moderate during Decmber-January, rapid during February-June and poor in July-November. Fast growth in February-June is correlated with rising salinity and the retarded growth during monsoon and winter with low salinity (Talikhedkar et al., 1978).

The size at sexual maturity at Palk Bay is 10-13 mm when the clams are 10 months old. They spawn for the first time from January to April when they are one year old and do not spawn more than twice during their life time (Nayar, 1955). Spawning has been reported from December to June at Madras (Rao 1967), and October to January at Ratnagiri (Nagabhushanam and Talikhedkar 1977a). The protein content varried from 56.59 to 68.31%, glycogen 11.14 to 25.85% and fat in 56 to 7.15% (Nagabhushanam and Talikhedkar, 1977b).

Biology of D. faba: It grows to a length of 19.5 mm in the first year and 23.5 mm at the end of second year at Mandapam. The life span does not seem to exceed 3 years. The clams reach sexual maturity at 13-14 mm length. Spawning is prolonged, extending from November to June with two spawning peaks in November- December and May-June. The average percentage edibility values ranged from 7.25 to 11.98 during different months and D. faba appears to be in the best condition during August-October and March-May period (Alagarswami, 1966).

Biology of D. incarnatus: At Goa spat that settled in April grew rapidly and continuously for 8 months reaching 21-22 mm length by December. Growth was slow for the next 12 months and few clams survived to reach this age (Ansell et al., 1972). The same authors obtained slightly slower growth for the same species at Cochin. Ayyappan Nair et al (1978) recorded a growth rate of 2.2/mm/month for the same species at Goa and observed that growth was influenced by availability of particulate organic carbon and chlorophyll a in the surf water. Bio-chemical studies on this clam from Goa showed that fat varied from 7.08 to 11.56%, carbohydrate 4.43 to 14.12% and protein 60.56 to 66.94% on dry weight basis (Ansell et al 1973). The average caloric value given by the same authors is 4650 cal/g dry weight.

Anadara granosa (Linnaeus)

Members of the genus Anadara are popularly called as ark shells, blood clams and cockles. A. granosa is widely distributed along the east and west coasts of our country. It grows upto 70 mm in length. It forms a fishery second only to the windowpane oyster in the Kakinada Bay.

Exploitation and fishery: A. granosa thrives well in soft muddy bottom with good amount of silt. In the Kakinada Bay this clam is fished in the region from the intertidal upto 4 m depth waters. Fishermen from 15 villages around Kakinada fish for the clams throughout the year with a peak in March-May. Annual production is estimated at 1000 tonnes valued at Rs. 50,000 (Narasimham, 1973).

Present status of utility: They are eaten locally to a limited extent and occassionally used as medicine. Shells are mostly burnt into lime in kilns locally known as batties with the meat in tact.

Biology: It grows to a length of 31.5 mm 49.5 mm at the end of 1st and 2nd year of life respectively. The commercial catches chiefly consisted of clams below 2 years old. It attains sexual maturity at 21 mm length when 7 months old and appears to spawn throughout the year with peak activity in January-April period (Narasimham, 1969).

In addition to the clams dealt in the foregoing account there are a few other species along our coasts which are fished to a lesser extent or practically unexploited but with a potential, mention may be made of the following.

Meretrix casta var ovum (Hanley): It grows to a length of 35-40 mm and is fished/the Kerala coast. /along

Tellina pinguis Hanley: It is a brackish water form and is among the important commercial clams on the Bombay coast.

Mesodesma glabratum (Lamarck): It is common on the coarse sandy beaches of the islands of Gulf of Mannar and is seldom fished.

Gafrarium tumidum Roding: Nearly 5 tonnes of this cockle clam are fished annually at Pamban and Rameswaram (Alagarswami and Narasimham, 1973).

Solen *Kempi* Preston: This has commercial importance near Ratnagiri where over 3 tonnes valued at Rs.2000/- are annually landed. It grows to a length of 52.5 mm at the end of first year. Spawning takes place between late October and March. Sexual maturity is attained when the clams are 5 months old. Diatoms and detritus form the bulk of its food (Rao *et* *al.*, 1962).

Cardium spp.

The true cockles belonging to the genus *Cardium* are not abundant in our waters. We have a few species like *C. asiaticum*. Bruguiere and *C. assimile* Reeve distributed at several places but they do not constitute fishery.

FISHERY AND BIOLOGY OF PEARL OYSTERS

K. ALAGARSWAMI

PEARL FISHERIES

The important pearl fisheries for the marine pearl oysters have been concentrated in Asia. On the other hand, the fresh water pearl fisheries were more popular in Europe and America. The major pearl fisheries in Asia have been in the Persian Gulf, Red Sea, India and Sri Lanka. To a small extent Japan had its natural pearl fishery. In Philippines and Australia, the pearl oysters were fished more for the shells than for the pearls.

In the Persian Gulf, the important pearling areas have been Bahrain, Kuwait, Dubai, Muscat and Bushire. There are more than 120 pearl banks in the Persian Gulf of which 60-70 rich banks are around Bahrain. The Red Sea pearl fishery was of great importance before the opening of the Suez Canal. Some beds are found even now in the Farasan Islands, South of Sabia and Jidda, West of Mecca. These beds are located on the Arabian Coast. In the Dongonab Bay along the coast of Sudan, the pearl shells are fished. In America, Gulf of California, Mexico, Panama and Venezuela have been important centres of pearl production.

In India, the two important areas for pearl fisheries are the Gulf of Mannar and Gulf of Kutch. There are over 60 well-known pearl oyster beds in the Gulf of Mannar at a depth of 10-20 m and at a distance of 11-16 km from the coast of Tamil Nadu. In the recent years, the fishery has been conducted with Tuticorin as the base of operations. However the pearl fisheries are intermittent and there are long gaps of unproductive periods between short spells of productive fisheries. In the recent years there have been annual pearl fisheries from 1955 to 1961 and thereafter the beds have again gone into the recessive cycle. Fishery prior to 1955 dates back to 1928. Over 80 million oysters were fished during the 1955-61 series. The Gulf of Kutch fishery is of a lower magnitude. Although the fishery used to be conducted once every 3 or 4 years, after 1966 there has been no pearl fishery in that area.

Nearly parallel to the Indian beds, pearl banks exist along the Gulf of Mannar coast of Sri Lanka. The production of these beds has been as fluctuating as that of the Indian beds. After a lapse of 33 years, a pearl fishery was conducted in 1958 which yielded 4.5 million oysters. Subsequently there were two minor fisheries in 1960 and 1961. Fishing for oysters is conducted in the Gulf of Mannar beds of India and Sri Lanka by skin-diving and collection of oysters. As an experimental measure, Sri Lanka introduced dredging operation in 1958. In the Gulf of Kutch, the fishery is conducted by handpicking as the beds are located in the intertidal zone. Fishing for natural pearls to-day is not even a fraction of what existed in older days. The Persian Gulf fishery has gone into oblivion as there has been no real interest. In India and Sri Lanka there have been no fishery for the last two decades as seen earlier. In Japan, Austrlia and Philippines cultured pearl industry has obliterated the natural pearling and every oyster found is used for production of cultured pearl. Even in the case of freshwater pearls, the beds of Europe have nearly vanished and those of the Mississippi-Tennessee Rivers of U.S.A. are not as productive for pearls as they were before. Thus we find that the natural pearl fisheries have very nearly been replaced by cultured pearl industry. Today one does not talk of the Orient or the Occident pearls but of the cultured pearls.

BIOLOGY

Species

In India at least six species of pearl oysters have been recorded. Of these, *P. fucata* is the only species which contributes to pearl production. In terms of abundance, *P. sugillata* and *P. chemnitizii* are next in importance on the mainland. In the Andaman and Nicobar Islands *P. margaritifera* is the most dominant species.

Habitat

P. fucata inhabits depths from 10-20 metres in the pearl banks of the Gulf of Mannar. The same species occupies the intertidal habitat in the Gulf of Kutch. Thus the species can adapt itself to different depth conditions within the above range. P. margaritifera has been collected from the intertidal flats of the Andaman and Nicobar Islands. The pearl oysters live attached to hard substratum such as corals, rocks etc., with the secretion of byssus.

P. fucata also tolerates a wide temperature range in its natural distribution. It occurs in pure tropical conditions in the Gulf of Mannar but lives under temperate conditions in Japan where the winter temperature goes down to about 10°C. The species, though stenohaline, can tolerate short term salinity fluctuations.

Feeding

Pearl oysters, like other bivalves, are filter-feeders and generally feed on phytoplanktonic organisms. Stomach contents also include bivalve eggs and shelled larvae which are in some seasons found abundantly. Copepods and crustacean appendages are also found. The pearl oyster is a wasteful feeder, and the filtering mechanism is not so efficient as to reject the unwanted materials at the time of food intake. Bivalve eggs, larvae etc. pass out not having been affected by the digestive process.

Growth

The growth of P. fucata is fast during the first year and reaches about 50-55 mm size during the first year. During the subsequent years the growth is slow. The life span is estimated to be 5 or 6 years and the maximum size is about 10 cm. There are considerable differences in the growth rate from environment to environment. Temperature, availability of food, calcium content of water, depth, clarity, current, load of fouling organisms etc., play an important role in the growth of the pearl oyster.

Spawning

P. fucata attains maturity at a very early stage when it is about 25-30 mm. The males and females are separate as a rule but hermaphroditic condition is observed in some individuals. In some species a change of sex from one spawning seaon to the next has been observed. Spawning has two peaks, about July-August and November-December, generally coinciding with the south-west and north-east monsoons respectively. Individual oyster spawns more than once in the same spawning season as the gonads are not emptied at one stretch.

Development

The eggs and sperms are shed by the spawning pearl oysters into the sea water and fertilisation is external. The fertilised eggs pass through the morula, gastrula, trochophore and straight-hinge stages before the typical molluscan valiger stage is reached in about 24 hours from fertilisation. Subsequent development takes the larva through the umbo and full-grown stage. The larva sets as spat when it is about 0.3 mm. The Japanese oyster completes these developmental stages in about 3 weeks.

Parasites and predators

Pinctada fucata has been reported to harbour quite a few parasites. The cestode Tetrahynchus unionifactor, trematodes Muttua margaritifera, Musalia herdmani and Aspidogaster margaritifera, and nematodes Ascaris meleagrinae and Cheiracanthus uncinatus have found to be the common helminth parasites. Some of these parasites, may play a role in the formation of natural pearls constituting the nucleus. Occasionally the pea crab Pinnotheres sp., is found in the body cavity of the pearl oyster.

Externally, a number of organisms constitute the fouling complex on the pearl oyster, the important among them being the barnacles, ascidians, bryozoans, molluscan spat and algae. Boring organisms such the sponge Cliona and polychaete Polydora can cause havoc to the shells.

The predators of pearl oysters are many. Octopus, file fishes and rays are the worst enemies which devour the oysters. Some of these can cause large-scale destruction of natural beds.

BIOLOGY OF PEARL

A pearl is merely an isolated concentration of the shell material made by the secretory mantle, which produces the main shell of the mollusc itself. When the pearl is formed in a nacreous shell, it is lustrous and qualified to be considered a gem. One produced in a porcellanous, dull, white shell will also be dull and porcellanous and will be only a concretion. The creation of a pearl may be considered an accident of nature. They are formed only when a foreign body becomes embedded in the mantle tissue or in any other tissue with a chance of a piece or a few cells of the mantle sticking on it as the foreign body makes its entry into the oyster. A pearl is also formed when the foreign body gets lodged between the shell and the mantle. Under the above conditions, unless the substance is rejected by the mollusc, it will be covered over by the mantle tissue in a few days forming a pearl-sac. The pearl-sac secretes the nacreous substance which gets deposited over the foreign substance which acts as the core material or nucleus of the pearl. Secretion and deposition of nacre continues with the life of the pearl oyster and a fine pearl is formed in course of time. Sometimes pearls are found without any trace of nucleus. In such cases at least a few broken cells of any tissue of the oyster or even the blood cells could have formed the nucleus. As these are not detectable they are called nucleusless pearls.

When the pearls are formed in the mantle or in any soft tissue of the oyster, they are free pearls. They are rarely round as they generally follow the shape of the nucleus. Also the pressure of tissues can cause flattening on some facets. Such irregular free pearls are called "baroques". The size of the pearl would depend on the size of the nucleus and the duration of the process of secretion. When the pearls are formed between the shell and the mantle, they are always attached to the shell and are therefore called blisters. Pearls of the finest nacre are produced by Pinctada fucata and P. maxima. P. margaritifera produces fine black pearls but very rarely. These pearls produced by the pearl oyster without the interference of man are called the natural pearls.

FISHERY AND BIOLOGY OF CEPHALOPODS

K.A. NARASIMHAM

The cephalopods are distributed in all the oceans of the world from shallow inshore areas to deep oceanic waters. They are purely marine in habitat. Among the cephalopods several species of squids, cuttlefishes and octopi are commercially important. Until recent times there was hardly any market for cephalopods in our country. Also the cuttlefishes are the first to be thrown out into the sea from the trawlers, immediately on hauling the net since the ink ejected by them contaminates the catch, particularly prawns (Silas et al., 1974). At present with the increasing demand, the export market for cephalopods has developed fast and they fetch a high price.

A large number of cephalopod species were recorded from our country (Silas, 1968; Oommen, 1977). The important commercial species like Sepia aculeata Ferussac and d' Orbingny, S. pharaonis Ehrenberg, Sepiella inermis (Ferussac and d' Orbigny) and Loligo duvauceli d' Orbigny which contribute to the fishery at several centres along the east and west coasts are widely distributed in the Indo-Pacific region.

EXPLOITATION AND FISHERY

The contribution of cephalopods to the marine fish catch in India varied from 1184 tonnes in 1970 to 15931 tonnes in 1978 (Table 1). They accounted for 0.1 to 1.14% of the total fish production. It may be seen from the table that since 1974 there has been a marked increase in the catches, due to the increased number of trawlers and also due to the insatiable demand for cephalopods in the foreign markets.

Except for the Palk Bay squid Sepioteuthis arctipinnis Gould there is no regular fishery for other cephalopods which are caught incidentally in small quantities along with fishes in gears like trawl net, shore seine, boat seine, gill net and cast net. In the Vizhinjam area hook and lines and scoop nets are also used. The shoaling behaviour and the migration to shallow waters for spawning by cephalopods in taken advantage in conducting regular fishing, as in the Palk Bay. Here the squid, S. arctipinnis migrate into inshore waters by about February and spawn till about June. During this period a shore seine called ola valai is used for squid fishing (Rao, 1954). The net consists of a rectangular bag of about 8m x 2m withclose and wide meshed webbing. The wing ropes measure about 274 m, bear 3-4 close set rows of palm leaf near the wings and 1 or 2 rows for the rest of the wing rope length. In the Palk Bay region special squid jiggs were used previously (Hornell, 1917) but now obsolete. In this method a fisherman keeps watch by sitting on a Y-shapped pole called machan. A long jigg of 5-6 hooks is arranged like a grapnel which is hidden under a heap of leaves near the machan to lure the squids. When they approach the leaves for spawning they are lifted with a jerk. Now a modified jigging method is followed in this area (Sarvesan, 1974). The jigg consists of 35-40 cm long slender wire equipped with 3-4 strong hooks on one end and the other is tied to a pole which serves as the handle. The fishermen in canoes or catamarans hook the squids with the jigg with a quick jerk. Also in the Palk Bay area the octopi, used as baits, are caught in shell traps (Sarvesan, 1974). About 100 to 120 gastropod shells like Lambis lambis, Tonna dolium, Raphna bulbosa, Murex birgineus and Hemifuses are strung along a thin coir rope. These lines are laid in 4-6 m depth with wooden floats attached. The traps are raised daily and the small octopi like Octopus dollfusi and O. globosus which take refuge in the shell cavities are dislodged with a needle to be used as bait.

Jigging is the most widely practised method, particularly by the Japanese in catching cephalopods. Multiple mechanical jiggs are now used by the Japanese. In California, lampara nets are used in squid fishing. The squid shoals, attracted by light during night time are encircled and hauled into the boat by power lifted dip nets.

While published information is lacking on the species wise cephalopod landings, it appears that the cuttlefishes are dominant, followed by squids and the contribution by octopi is negligible.

Future outlook: The exploratory surveys along the west coast revealed the occurrence of commercially important species of squids such as Symplectoteuthis oualaniensis and Loligo spp. (Silas, 1969). There is need to try special fishing methods such as light fishing with jiggs to exploit the squid resources (Silas et al., 1974).

Present status of utility: Apart from their utility as food for man cephalopods are important forage organisms for fish, birds and mammals in the sea. At present as food they are not a popular item in our country. However in recent years significant progress was made in the export of cephalopods to foreign countries. In 1978 frozen squids weighing 2428 tonnes (value Rs. 3.28 crores) and frozen cuttle fish weighing 979 tonnes (value Rs. 1.66 crores) were sent to a number of countries, France being the main importer. In 1977 cuttle bones weighing 49 tonnes (value Rs. 2.99 lakhs) were exported. The cuttlebones are a source of calcium. They are used in the preparation of abrasives and dentrifices. Also wooden or metal surfaces are polished with cuttlebones.

BIOLOGY

Food and feeding habits: The cephalopods are carnivorous and they hunt their prey by sight. Their well developed eyes help them to pursue the prey. The flexible muscular arms and tentacles with their suckers give them a strong grip over the prey. The powerful jaws present in the buccal mass help to cut the prey into pieces. Fishes, crustaceans and cephalopods are the important food items consumed by them.

Rao (1954) stated that spawners of Palk Bay squid in general do not feed during the spawning period. High feeding intensity in L. duvauceli was observed (Oommen, 1977) during February-May and the squids obtained during night time had few empty stomachs (Oommen, 1976). The studies by Kore and Joshi (1975) also indicated that the squid is carnivorous, cannibalistic and shows seasonal variation in the intensity of feeding. In S. inermis high feeding intensity was observed in April-May and no such periodicity was found in S. aculeata (Oommen, 1977).

The squids are known to change their food with growth. Vovk (cited by Arnold and Arnold, 1977) reported that in Loligo pealei planktonic feeding was dominant in the smallest size squid (75 mm mantle length). Euphausid feeding became important to larger squid (125 mm length). Cannibalism and fish feeding dominated in sizes larger than 160 mm. Kore and Joshi (1975) also reported in L. duvauceli an increase in cannibalism and decrease in crustacean feeding for larger squid.

Growth: Rao (1954) concluded that S. arctipinnis attains an average mantle length of 95, 166 and 219.5 mm at the end of 1, 2 and 3rd year of life respectively. Males grow to a larger size than females. For other species published data are lacking.

Maturity: In S. arctipinnis males attain sexual maturity between 67.5 to 112.5 mm length when they are 6-14 months old; females mature at 102.5 to 112.5 mm when they are 12-14 months old. No published information is available on other species.

Fecundity: Summers (1971) estimated that mature females of Loligo pealei lay between 3500 to 6000 eggs depending on their size. Octopus vulgaus is perhaps most prolific, laying 1,50,000 eggs over a period of few days. At the other end O. bimaculoides lays a few hundred eggs (Akimushkin as cited by Wells and Wells, 1977). For Indian species there seem to be no published data available.

Spawning: In S. arctipinnis spawning commences in January and is continued till the end of June (Rao, 1954). Squids migrate into shallow inshore waters and adjacent lagoons from the offshore waters by about February and deposit their eggs capsules till about June. Squids and cuttle fishes are known to exhibit elaborate courtship before mating.

The eggs are deposited singly or in clusters on sticks, rods or on floating objects. Females show a tendency to lay on existing clusters. A common site may be used by many females for egg laying for extended periods and large masses are built up. In majority of cephalopods about which information is available, mating behaviour and/or egg laying is followed by death (Arnold and Arnold, 1977). Octopods to not swarm to breed (Wells and Wells, 1977).

Fertilisation and development: In cephalopods the spermatophores are transferred along a groove in the hectocotylus from males to the mantle cavity of females and fertilisation is internal. The pattern of development is generally uniform in cephalopods if allowance is made for the variable amount of yolk (Arnold and Arnold, 1977). Alagarswami (1966) studied the embryonic development of the squid referred to S. arctipinnis on corroborative evidence. The early cleavage is of meroblastic type resulting in 64 celled stage. By further marginal divisions of the blastomeres the blastoderm separating the embryonic and non embryonic regions. On the 5th day the organ forming areas are noticed and differentiation of various organs is in progress. On the 7th day the embryo is far advanced in development and more organs like the formation of lense in the eyes are developed. By the 14th day the developing embryo appears as a miniature adult but still with yolk sac attached. The mantle, fins, arms, eyes and the visceral organs are all well developed and the embryos move inside the chorion. On the 15th day the young hatch out and they resemble very much the adult. They begin an independent life.

Octopods brood their eggs (Wells and Wells, 1977). Parental care in O. dollfusi was described by Sarvesan (1974).

Larval history: Properly speaking there are no larval forms in Decapoda. Development is direct to a miniature adult which may or may not enter into a planktonic type of existence before forming typical schools or sedentary life styles (Arnold and Arnold, 1977). In the

Octopoda also, Wells and Wells (1977) advocate that the term 'larva' be better avoided.

Table 1: Cephalopod and total fish catches (Source: C.M.F.R.I. Annual reports)

Year	Total Fish Catch tonnes	Cephalopods tonnes	% of Cephalopods
1970	10,85,607	1,184	0.12
1971	11,61,389	1,505	0.13
1972	9,80,049	1,026	0.10
1973	12,20,240	1,394	0.11
1974	12,17,797	3,677	0.30
1975	14,22,693	7,889	0.55
1976	13,52,855	10,826	0.80
1977	12,59,782	10,005	0.79
1978	14,03,607	15,931	1.14

TECHNOLOGY OF EDIBLE OYSTER CULTURE

K. NAGAPPAN NAYAR

CULTURE METHODS

In oyster culture there are two important major aspects (1) production of seed and (2) growing the seeds to marketable size. This paper deals only with the latter aspect of oyster culture.

In order to grow oysters five different culture methods are generally followed with slight modifications from country to country. They are (1) raft culture (2) rack culture (3) long-line culture (4) stake culture and (5) on-bottom culture.

Raft culture

Rafts can be made to any convenient size. Most of the rafts used in Japan are of the standard size of 16 x 25 m and each carries a total number of 500 to 600 wire rens. The rafts are constructed by using 75-100 cm diameter bamboo or cedarpoles lashed together with wires in 2 layers at right angles to each other and with the poles 0.3 to 0.7 m apart. The rafts are buoyed up by hollow concrete drums, tarred wooden barrels or styrofoam cylinders. Depending on the increase in weight due to growth of oysters, additional floats are added. Rafts are laid at 1.6 to 3 m apart, tied together with ropes with two anchors at each end. 10 or more rafts are tied by this method. Although different materials are used for making rafts, it has been observed that the log rafts are more suitable than light floating materials such as pontoons or styrofoam since they tend to bounce considerably with the slightest wave action. This causes the strings to weaken and break.

Rack culture

Rack culture is possible only in shallow, and calm seas of 1 to 4 m in depth. Two rows of posts, are planted vertically in the sea bottom and a rack is prepared by fixing horizontal posts on them at a convenient height from the bottom so that the platform thus erected remains always submerged in water. Where the depth is more than $2\frac{1}{2}$ m, strings of oysters are suspended from the platform in such a way that they do not touch the bottom. If areas where the depth is less than $1\frac{1}{2}$ m, oysters can be kept on suitable trays over the constructed platform. At Tuticorin, the rack and tray culture method is being followed, and Crassostrea madrasensis is grown. The platform is so constructed that it can carry two rows of 10 trays each. The trays fabricated for this purpose are rectangular and 90 x 60 x 15 cm in dimension. The frame of the tray is of 6 mm welded steel and is coated with lacoloid black paint as an anticorrosive measure. To the said frame 2 mm nylon twine netting of 20 mm mesh size is knitted at the sides and bottom. The nylon meshed trays are strong enough to bear the weight of the oysters, at the same time permits free water flow along with nutrients and feed organisms. The spat when they are scraped are graded and transferred to suitable meshed cages (15 mm or 25 mm mesh size) and suspended from the platform of the racks. The growth of young oysters is very good during the initial period and it shows an average of about 12-15 mm per month and reaches a size of 40 mm within a period of 3 to $3\frac{1}{2}$ months. At this size they are transferred to the usual rectangular trays and kept over the platform for further growth. Majority of the oysters attain a size of 90 mm in 12 month period when they are ready for marketing. By following the rack and tray culture method it has been possible to produce 120-150 tons of oysters per hectare which will give a total meat weight of atleast 12 tons.

Long-line culture

The long-line culture method developed in Japan is a modification of the raft technique. The basic longline unit consists of a series of wooden barrels underwhich two parallel longlines of 6 centimetre rope are tied. The floats are spaced at a distance of 7 metres apart and the rens are suspended from the rope. The length of the ren is usually 7.5 to 10 m, depending on the depth of the water column. Rens should not be allowed to touch the bottom at any time. The long-lines are so variable in length and depth that no generalization can be made concerning their yield. It has been reported that a 60 m long longline in Japan consisting of 11 tarred wooden floats with 300 m rens produces 1.2 tons of shucked meat in 18 months growing season. In one ha. 44 such longlines could be accommodated which would give a potential yield of 53 tons of oyster meat. Long lines operated in still deeper waters with 15 m long rens may give a higher yield per ha. In addition to the low initial expense and maintenance costs, longlines possess the advantages of withstanding winds, waves, and currents better than rafts. This method has made it possible to grow oysters in unprotected areas in the open sea where raft culture is not possible and thus appear to be a step forward in oyster culture procedures. The gradual increase in Japanese oyster production over the past decades is due to the utilisation of such areas.

Stake culture

This is also an old method and has many disadvantages since the growing oysters are not protected from crawling predators. In this method the seed oysters are attached to wooden stakes driven into the bottom in the intertidal zone. This method is becoming unpopular because of the lack of suitable areas in shallow regions in most of the major oyster growing countries.

On-bottom culture or sowing method

This is a primitive method wherein the oyster spats are placed directly on the bottom, and allowed to grow with periodical monitoring till they are harvested. As the production rate is very low, in most of the places, this method has been discontinued making way for raft culture system in deeper waters as in the case of Japan where the production rate is much higher. In U.S.A. which is one of the leading oyster producing countries of the world, the traditional on-bottom culture method is still followed because of economic considerations.

ESTABLISHMENT OF AN OYSTER FARM

Before establishing an oyster farm the following points will have to be satisfied:

1. Site selection and environmental conditions: The area should be fairly well protected from strong winds and waves and should have sufficient depth too. The quality of the water should be very good and it should not be an area polluted by domestic or industrial waste. During rainy seasons the salinity should not be too low since the oysters may not be able to tolerate it. Water samples should be taken and analysed to find out the availability of nutrients to support growth of those species of algae which are utilized by the oysters. Although food levels can be estimated from examination of plankton, test planting of oysters are necessary to determine the adequacy of natural food supplies. Prior study for the prevalence of 'red tide' organisms would also be useful.

2. Availability of seed oysters: Natural setting of oysters varies with location and season. In some places oysters may grow well, but natural setting may not take place always. If natural method of spat collection is not possible then the possibility of introducing seeds from nearby spat collection areas will have to be explored and the economics of collection and transport also should be worked out. It is always better to get the seed from the oyster hatchery, if that is possible and economical, since they try to produce increased disease-resistant seeds and also better quality strains. As a general principle, native species should be used wherever possible to avoid the transfer of predators, parasites and diseases or the introduction of species which will replace more desirable local forms. In some places it may be necessary to introduce exotic species where there are no oysters or where the native species are not suitable for commercial culture. In such cases it is always better to transplant hatchery produced seed oysters.

CONTROL OF DISEASES, PREDATORS AND FOULING

Mass mortalities of oysters, often due to unexplained causes, are known to occur wherever oysters are grown and only ina few cases the causative organism has been identified. Predators such as boring gastropods, starfishes, crabs and skates may cause extensive damage to the cultured oysters. Hence suitable control methods will have to be followed. In some cases fouling organisms such as barnacles, sponges, various species of algae and other organisms settle on the oysters and affect the growth of oysters. Suitable control methods both chemical as well as physical will have to be followed.

SCOPE FOR OYSTER CULTURE

Suitable methods of harvesting also will have to be thought of depending on the type of culture method adopted. The economics of oyster culture also will have to be properly studied before starting a big commercial venture. Extension work has to be taken up to popularise the oyster meat at least in some of the selected places so as to create a good demand. As some of the oyster growing countries are not able to produce sufficient quantities of oysters to meet the local demand, they have resorted to import of oysters (mainly canned) from other countries. For instance Korea was not an oyster producing country till 1958. Because of the government policy to develop oyster culture and also due to the availability of suitable extensive shallow bays protected from storms by surrounding hills, the oyster culture was taken up on scientific lines and today the Republic of Korea is one of the leading oyster producing countries in the world.

TECHNOLOGY OF MUSSEL CULTURE

P.S. KURIAKOSE

Five different techniques are used in mussel culture (1) Sea bottom culture (2) Pole culture (3) Rack culture (4) Long line culture (5) Raft culture.

Sea bottom culture

This technique is widely practised in Netherlands and in a number of European countries including Denmark and West Germany. The principle of bottom culture is the transfer of seed or juvenile mussels from areas of great abundance where growth is very poor due to over-crowding to areas where mussels can grow faster. The basic requirement for this technique is a firm substratum free from drifting sand and mud particles. Seed mussels are dredged from public grounds and laid first on shallow grounds where they will grow. They are later transferred to deeper grounds for fattening. Mussel farmers sow a thick layer in the shallow grounds. When the mussels reach a length of about 25-30 mm they are thinned out by transferring the excess portion to deeper areas for fast growth and fattening. When mussels are 2 to 2½ years old they attain a size of about 60 to 70 mm and is ready for harvest. The mussels are dredged and dumped in a thick layer in an area of little tidal movement free from drifting sand. They are left for 48 hours to rid themselves of silt. The chief advantage of bottom cultivation is that the mussels always remain under water and therefore feed longer. The main drawbacks are exposure to bottom predators like star fishes and crabs, and need to cleanse the mussels of silt.

Pole culture or Bouchot method

Pole culture is the oldest and principal method of mussel farming in France. In this method mussels are grown on rows of poles in the intertidal area. The extreme tidal range is advantageous to mussel grower. Mussel seeds or spat are collected on spat collector poles closer to the land. The poles are 75 cm apart, and are set in rows at right angle to the shore. The seeds are attached to the rearing poles in bags of fine netting which rot and fall apart after the mussels attach themselves to the poles, by byssus threads. As the mussels grow they are thinned out and transferred to other rearing posts. Another seed collection technique recently practised in France involves suspending loosely woven ropes 13 mm in diameter and 3 metre long in the inter tidal region near natural beds. Within 3 weeks after spawning seed mussels of about 5 to 10 mm size attach themselves in the crevices between the strands of the ropes. The ropes are then wrapped around poles driven in the inter-tidal flats. The procedure is similar to the traditional method. The mussels are thinned out periodically as they grow and wrapped round other poles. By the end of second year the mussels are harvested, and marketed after reaching a size of about 50mm. The average production is about 25 kg of mussels each year for every pole used and per hectare yield is about 4.5 tonnes per year.

The main advantage of pole culture is that the mussels are less exposed to the bottom living predatory crabs and star fishes. Predation is further reduced by the adoption of plastic sheaths around the base of the pole. The main drawback however is that, the mussels are exposed at low tide especially on spring tide. The poles are vulnerable to storms.

Rack culture

Mussel farming on racks is practised in Italy. Though the mussel farmers do use mussel seeds which settle naturally on rocks and other hard substrates as primary materials by far the largest part of the seed requirement is met from artificial collectors. In the sheltered area where the mussel farming is practised, the bottom is predominantly soft and muddy. The mussel farmers construct parks comprising net works of poles connected with horizontal ropes. From these ropes they suspend strings of mussels which are permanently in sea water above the bottom. A special type of rope is stretched around the park to collect the seed. Growth is very rapid and the mussels will be ready for harvest when they attain a size of 100 mm.

Long line culture

The long line method of mussel farming was introduced very recently in Europe. This method is very successful in open sea mussel farming. Long lines are 50 to 75 metre long and consist of a pair of ropes strung between two parallel pair of metal, wooden or styrofoam floats. Each end of the line portion is (some times the middle also) is anchored. Floats are spaced 3 to 7 metres apart. Mussel seeds are collected from natural beds and transplanted on the ropes and suspended from lines about 0.5 metre apart. The growth in this system is very rapid.

Raft culture or suspended culture

The raft culture technique has undergone great development in recent years offering the best prospects for farming of mussels in sheltered and open coastal waters. This method is generally used in waters more than 3 metres deep. The modern rafts commonly have four or more large wooden floats covered with cement or fibre glass to protect the wood from marine borers. On the top of the floats frame work of wooden beams are provided, about 50 to 60 cm apart, from which the ropes are hung. The raft is usually fitted with a working deck and shelter for the operators. The size of the raft varies but an average raft is 20 x 20 metres and will accommodate 500 ropes. Recently large-scale operator's have constructed more rugged rafts about 700 sq.m for use in deeper and exposed waters. Such rafts can hold 1000 ropes and are streamlined to withstand strong currents.

During the peak spawning period empty fibrous ropes are hung from the rafts for collecting spat. The ropes are soon crowded with young mussels. The mussels grow rapidly and generally reach a size of about 30 to 40 mm within five months. Thinning is done when the mussels are 25 to 30 mm long. The mussels are removed from the ropes and bound on to new ropes using thin large meshed cotton or rayon netting. One "Settlement" or "Collector" rope yields enough mussels for twelve to fifteen new ropes.

Seed mussels gathered from the inter tidal rocks are wrapped round ropes and suspended from the rafts. At every 30 to 40cm length a wooden peg of about 12 mm square is inserted between the strands on each rope to prevent mussels from sliding. When the mussels reach a size of 70 to 90 mm they are harvested. A mussel culture raft of about 250 square metre surface area can hold 400 ropes. One hectare area in the sea can easily accommodate 30 such rafts with 12,000 ropes. The average production per rope of 8 metres length is about 30 kg of mussels.

In India experimental mussel culture farms are mainly located in the coastal waters up to a depth of 10 metres. Only raft culture method is followed. A raft of the size 8 x 8 metres can safely hold up to 100 mussel ropes. Teak-wood or casurine poles are used for the main frame work and bamboo poles for more strength and suspending the mussel ropes. Sealed and empty metal drums or high density plastic drums are used as floats. The raft is anchored with 3 iron anchors each of 100 kg weight. Knitted cotton cloth having a mesh size of 5 mm is used for seeding. Growth of mussels is very quick attaining marketable size of 75-80 mm in 5 months. In the case of brown mussels the harvest size of 60 mm is reached in 8 months.

TECHNOLOGY OF PEARL CULTURE

K. ALAGARSWAMI

The cultured pearl is a pearl which is produced in the pearl oyster by the deliberate attempt of man providing the two basic conditions: i) in the place of accidental entry of an foreign aubstance, the core material called nucleus is implanted in the oyster's body; and ii) in the place of chance formation of pearl-sac by mantle epithelial cells, a piece of mantle called graft tissue is planted on the nucleus to ensure formation of the pearl-sac. Under these conditions the pearl-sac is formed around the nucleus and the epithelial cells secrete and deposit nacre on the nucleus which finally turns into a pearl. As the initial act of providing the basic setting is done by man and the oysters are cultured under controlled conditions, the pearl produced by this process is called the "cultured pearl".

SPECIES EMPLOYED IN PEARL CULTURE

Among the pearl oysters, of which several species occur in the world, three are of great importance in pearl culture. Pinctada fucata is numerically the most significant species producing the finest cultured pearls. P. maxima, the largest among the pearl oysters produce exceptionally large cultured pearls of a fine quality. P. margaritifera, the black-lip pearl oyster produces fine black cultured pearls. The winged oysters Pteria penguin and P. macroptera are used in pearl culture in some areas. The abalone Haliotis discus is used in a small measure in pearl culture.

In the fresh water system, the mussels Hyriopsis schlegeli and Cristaria plicata are used to produce fine salmon pink pearls.

TECHNIQUES OF PEARL OYSTER FARMING

Raft culture is the standard method for the farming of pearl oysters. Rafts are constructed of bamboo or wooden poles, placed length-and breadth-wise appropriately and lashed with ropes. The dimensions of rafts and number of units per line vary from place to place. The raft is buoyed up by using cylindrical barrels, wooden, metal or synthetic, and moored with anchor and chain. Oysters collected from the wild or grown from spat are placed in frame nets or boxes and suspended from the rafts at chosen depths. Calm bays are preferred for pearl culture for maintaining the rafts throughout the year. The desirable minimum depth is about 10 metres, although it is possible to culture oysters in shallow waters of about 5 metres depth.

Maintenance of farm required periodic cleaning of oysters. A large number of fouling organisms such as barnacles, bryozoans, ascidians etc. settle and grow on the oysters in the farm and these have to be cleaned at regular intervals depending on the intensity of fouling. Besides competing with the oysters for food, they cause stress on the oysters. Heavily fouled oysters do not produce good quality pearls. Boring organisms such as the sponge Cliona and polychaete Polydora cause extensive damages to the shells and need tobe controlled. Simple methods such as dipping in fresh water or in brine, or smearing of 1% formalin can kill the boring osganisms. In the tropical inshore waters the biofouling and boring problems are quite severe.

The interest of pearl culturists is slowly reverting back to bottom culture and experiments are being conducted in Japan and Australia to culture oysters in cages placed on or close to the sea bottom.

TECHNIQUES OF PEARL PRODUCTION

After the oysters have grown in the farm and reached the size required for initiating pearl production, they are brought to the laboratory. Pearl production can be divided into two phases, the laboratory phase and farm phase. The former is of a very short duration and the latter is an extended one, the duration depending on the size of pearls programmed.

Laboratory phase

Selection: Proper oysters for the surgery as also for graft tissue preparation should be selected. Diseased oysters and those with extensive attack by borers should be discarded.

Cleaning: The oysters should be cleaned of all external growth of fouling organisms and encrustations.

Conditioning: This is done by narcotising the oysters in menthol. The oysters are kept in sea water in vessels and menthol crystals are spread on the water. Approximately in 1½ hours the oysters are ready for use in surgery. The Japanese use physical exhaustion and thermal variation methods for "egg extraction" and conditioning purposes.

Graft tissue preparation: Both the mantles of an oyster are cut, cleaned and trimmed. The ribbon obtained is fractioned into several pieces each of about 2-3 mm x 2mm. The pieces are kept moist on clean soft wood boards until used. Smearing of the tissues with a weak solution of eosin helps to keep them without deterioration for some time.

Nucleus: Spherical beads of 2-8 mm diameter are used as the nuclei. These beads are generally made of fresh water mussel shells which are hard and white and have the density about equal to that of mother-of-pearl. For the Japanese pearl culture industry the supply of the mussel shells comes from U.S.A. These are processed by machines into spherical beads of required diameters. In India, the chank shells which largely meet the specifications have been processed into beads and used in experimental pearl production.

Before commencing surgery, the programme for proposed pearl production must be decided and the size of oysters, nucleus and graft tissue should be selected on this basis.

Surgery: This is a delicate operation for the implantation of the graft tissue and the nucleus within the tissues of the oyster. Specially designed instruments are used in the surgery. The conditioned oyster is mounted on the stand. An incision is made at the base of the foot of the oyster and a canal is cut through the gonad below the epithelium without damaging the stomach or the intestine upto the predetermined site of implantation. In the case of single implantation the site is close to the turn of the intestinal loop. In double implantation a second site is chosen close to the hepatopancreas. In multiple implantation several other sites between the above two are selected. A piece of mantle is inserted through the canal and left at the site in proper orientation. This is followed by the implantation of the nucleus at the site in contact with the graft tissue. After the surgery the oysters are left in tanks for recovering from the effects of narcotisation and the surgery.

In the production of half-pearls, the nuclei, which are made of alabaster, are stuck with a glue which can cure in water on the inner aspect of the shells of the pearl oyster. Depending on the size of the oyster, a number of such alabaster beads are used on both shells.

Convalescence: Where the sea adjacent to the laboratory is calm, the operated oysters are placed in cages and suspended from the rafts immediately after the surgery. Where such conditions are not available, the oysters are kept in the laboratory with continuous water supply for a period of 2-3 days. The operated oysters must be handled very carefully causing minimum disturbance. Exposure to violent conditions will result in the slipping of nuclei.

Farm phase

After convalescence, the oysters are taken to farm for the post-operative culture. The outer epithelium of the graft tissue grows over the nucleus and forms the pearl-sac within a week. The nacre secreted by the pearl-sac epithelium is deposited on the nucleus and the nacre grows in concentric manner in thin lamellae.

During this phase the oysters are disturbed the least. The duration of culture varies depending on the programme of production. In the Gulf of Mannar, in the case of pearls 3 or 4 mm diameter the harvest is done at the end of 3 months (from surgery). Inthe case of larger pearls of 7 or 8 mm the duration is about 18 months. In the Japanese waters, for similar sizes of pearls the duration ranges from 6 months to 3 years. In the tropical waters, the rate of deposition of nacre is much faster than in temperate seas and secretion is almost continuous.

Harvest is done usually when the temperature is on the lower side so that thinner layers of nacre are obtained on the periphery of the pearl. The oysters are brought to the shore and cut open to remove the cultured pearls.

PEARL PRODUCTION

Normally about 60-65% of the seeded oysters surviving to harvest produce pearls. In double and multiple implantations, the rate of production in respect of number of oysters used is much greater. Rate of slipping of nuclei can be reduced and kept to the minimum by careful surgery. Mortality and slipping rate are relatively greater when larger nuclei of 7 or 8 mm diameter are employed. Observance of proper care at all stages can improve production rate.

The pearls produced are a mixed lot in terms of quality. Production of about 40% of round, lustrous pearls of top quality can be considered a good performance. The rest will have blemishes and some may be misshapen. The colour of pearls also varies. Factors such as genetic characteristics, depth of culture, physiological condition of the oyster, site of implantation, nutrition, chemical composition of sea water and plankton, trace elements and the laminar structure of pearl contribute to difference in colours of pearls. Colour adjustment or improvement is possible within certain limits through bleaching and dyeing.

STRUCTURE OF PEARLS

The cultured pearl has a core shelly material over which concentric layers of nacre have been formed. The nacreous layer essentially consists of two materials - an organic proteinous substance called conchiolin and a mineral substance of calcium carbonate. About 92% of nacre is composed of calcium carbonate and conchiolin forms about 4%. The organic substance forms the matrix on which the mineral substance is deposited. The latter, in the form of aragonite crystals gives rise to good quality pearls, but in calcite form would result in dull porcellanours pearls. The organic and mineral substances are deposited in very thin layers, the thickness of each layer of the former being about 0.02 microns and that of the latter being about 0.29-0.60 microns. A regular laminar structure of nacre gives the pearl the iridescence and lustre.

TRENDS IN TECHNOLOGY

The current trends in pearl culture researches in Japan aim at improving quality of pearls rather than increasing production. From about 130 tonnes of cultured pearls in 1966, it has fallen to around 35 tonnes and the Japanese culturists would like to stablise production around this level but to improve quality. Genetic improvement of stocks, hatchery production of seed, and improvements in the culture environment, are some of the areas in which research efforts are directed. Tissue culture of mantle epithelium for pure culture of fine aragonite secreting tissues is another area receiving attention. Ground culture of oysters has evoked interest in the recent years both in Japan and in Australia. Attention has been turned on P. margaritifera for improving the production of fine steel black free pearls at several centres. In India, where a consierable amount of technical knowhow has already been built up the present concern is on developing hatchery seed production technology to ensure a stable production of pearl oysters, refinements in pearl production to improve quality of pearls, development of techniques for large-scale production of nucleus and pearl culture environment management.

TECHNOLOGY OF CLAMS AND COCKLES. CULTURE

K.A. NARASIMHAM

Cultivable species

Good number of clams are at present cultivated in a number of countries (Table 1). It may be seen that clam/cockle culture is extensively practised in Japan, Korea, Taiwan, Malaysia and Thailand. True cockles belonging to the genus *Cardium* are not commercially cultured but the blood clam *Anadara granosa* which is referred to as cockle in the south-east Asian countries is extensively cultured. In our country, apart from the 4 species given in the table, *Katelysia opima* and *Vellorita cyprinoides* var *cochinensis* have the potential for farming.

Induced spawning and hatchery production of seed

The procedure is popularly known as the Milford method (Bardach *et al.*, 1972) and is the same as followed for oysters. In short the adult clams are held at 10°C and are conditioned for spawning by slowly raising the temperature to about 18°C. For 2-4 weeks the temperature is maintained at this level depending upon the time of the year. Then it is raised to 25°C which induces spawning. The larvae are reared in the hatchery supplied with sterilised water. Algal cultures of *Monochrysis lutheri* and *Isochrysis galbana* are given as feed. When the larvae are ready to settle they are transferred to larger settling tanks for rearing the spat. By this method the quahog, *Mercenaria mercenaria* was spawned in the U.S. and the seed raised. A great advantage of this method is that the clams can be induced to spawn at any time of the year which would ensure continuous seed supply.

Seed collection

The size of the seed collected from the wild varies even for the same species at a given locality depending upon the time of collection. In Taiwan (Chen, 1976) where there is a practice of nursery rearing of seed, seed measuring 0.5 mm length onwards are collected. Otherwise for most of the commercial species 5-25 mm seed are collected. The equipments required are a spade, rack or any implement suitable to dig the top layer of substratum. In mud flats, for Anadara seed, a small hand net with nylon mesh netting is scooped in the mud or operated from a boat. Propulsion on mud flats may be on a wooden plank with one foot pushing through the mud while kneeling on the plank with the other leg. Sieves are used to separate the seed. Hand picking is a common practice for slightly larger seed. Also a container like a bamboo basket, wooden box, trough etc., is carried to hold the seed collected. Seed collection is usually done at low tide.

Nursery rearing of seed

In Taiwan tiny seeds (about 0.5 mm in length) of Meretrix lusoria are gathered from sandy flats in tidal areas by sieving the substratum (Chen, 1976). They are stocked in milk fish ponds at 30 to 50 million per hectare. Bamboo sticks are planted to serve as markers. If the productivity in the pond is poor fertilisers like night soil, hog manure, chicken droppings, rice bran etc., are applied. Predators are removed periodically. After about 6 months nursery rearing they are harvested (survival 50-60%) and sold for stocking in clam farms. Similar nursery management of the seed clams of A. granosa is in vogue in Taiwan (Chen, 1976) where they are reared for a few months in mud flat enclosures (area 0.1 to 0.3 ha) made of nylon netting supported by bamboo sticks.

Site selection

The clam farms are located in estuaries, bays and other sheltered areas close to the shore having tidal influence. About 1-2 h exposure at each low tide has the obvious advantage of managing the farm with ease. Too long an exposure results in poor growth due to reduced feeding and may cause mortality due to desiccation. Farms located farther in sub-tidal area have the disadvantage when predators are to be eradicated. Clams are rarely grown in ponds. In Taiwan (Chen, 1976) Meretrix lusoria is grown in ponds formerly used for milkfish and also in the outlet and inlet canals of milk fish ponds. The type of substratum preferred varies with species cultured. For example Meretrix sp., thrives well on sandy bottom while Anadara granosa prefers mud flats containing upto 90% silt. Also the range of salinity tolerated differs. Few species tolerate prolonged low saline conditions which are generally prevalent in areas subjected to heavy rains or fresh water drain from the land. Clam farms should be located in areas where there is little wave action. Areas prone to frequent changes of contour and liable to pollution should be avoided. It is also desirable that the clam seed is available close to the farm site.

Equipment

Very little equipment is required for clam farming. Bamboo sticks are planted to indicate the farm area. The movements of the clams are limited and fencing is not necessary. However synthetic fibre nets are sometimes erected as in Taiwan (1976) and U.S.A. (Bardach et al., 1972) to prevent their escape with the water current and/or to keep the predators (crabs and fish) away. A watchman's shed and a bamboo raft or a boat for transplanting, harvesting and inspection are required depending on the size and location of the farm.

Farming the clams for market

The ground should be levelled and cleared of predators. The clam farm is generally stocked at high tide. The seed may be sown from boats, taking care to get even dispersal. Any irregularity observed in the distribution is set right at the next low tide. The stocking density varies generally depending upon seed availability and the species cultured. In the case of A. granosa, in Malaysia it may reach 1000 to 2000/m^2 and this may be thinned more than once to achieve a final density of 300 to $600/m^2$ (Bardach et al., 1972). The duration of the culture depends upon the species and the country where grown. M. mercenaria when grown in northern waters of U.S.A. takes 5-8 years to reach marketable size and the same species when cultured in Florida could be marketed in 2 years (Bardach et al., 1972). Similarly A. granosa is cultured for 1-2 years in Taiwan, 8-9 months in Malaysia and at Kakinada it was harvested after 5 months culture (Narasimham, 1980).

Farm management and harvesting

The natural enemies of the clams are the boring gastropods, starfishes, crabs, skates and wild ducks. Therefore a close watch for predators is remunerative. The farm needs very little maintenance job. In clam culture fertilisers and feeds are not used. Care should be taken to prevent poaching. Harvesting is usually done by hand. Some of the implements used in seed collection are employed in harvesting. A dredge may also be used. The yield by clam culture varies widely in different countries, being invariably low in temperate countries. For example the production of A. granosa is less than a tonne/ha/year in Taiwan, 20.7 tonnes/ha/year in Malaysia and at Kakinada a very high production of 385.3 kg/$100m^2$/5 months was obtained at a stocking density of $140/m^2$ (Narasimham 1980). In Malaysia usually clams are stocked, 300 to $600/m^2$.

Economics

Data on cost benefit studies are available for a few clams. In Malaysia a 16 ha Anadara farm showed a gross profit of 6333 to 7600 US dollars (Fisheries Division, 1972) and in Thailand a 1.6 ha farm gave a net return of 1478 US dollars (Sribhibhadh, 1972). In Korea the net income from a 50 ha hard clam farm was estimated at 6870 million wons.

Clam culture prospects in India

On bottom clam culture is fairly simple. Experimental culture on the 'on bottom culture' of various clam species being undertaken at the Central Marine Fisheries Research Institute indicates that the clams grow very fast and reach marketable size in 5-6 months and their production per unit area is very high. As is the case with other edible molluscs, clam culture offers immense scope for coastal aquaculture.

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Table 1. Important species of clams and cockles cultured

Scientific name	Popular name	Family	Country where cultivated	Extent of development	Area under cultivation	Reference
Meretrix meretrix	Hard clam	Veneridae	Taiwan	Extensive	---	Ling (1972)
	Great clam	"	India	Experimental	---	
		"	Korea	Extensive	3396 ha	Office of Fisheries (1972)
		"	Japan	Extensive		Ling (1972)
		"	Taiwan	Extensive	3799 ha	Chen (1976)
M. casta	Backwater Clam	"	India	Experimental	---	
M. casta var ovum		"	India	Experimental	---	
Venerupis semidecussata		"	Japan	Extensive	---	Ling (1972)
V. decussata	Little neck clam	"	Portugal	Moderate	---	Korringa (1976)
V. japanica	Short necked clam	"	Korea	Extensive	888 ha	Office of Fisheries (1972)
Tapes japanica		"	Japan	Extensive	---	Bardarch et al (1972)
Mercenaria mercenaria	Hard clam, quahog	"	U.S.A.	Limited extent	---	Iverson (1976)
Anadara granosa	Cockle, blood clam	Arcidae	Malaysia	Extensive	2000 ha	Fisheries Division(1972)
		"	Thailand	Extensive	625 ha	Sribhibhadh (1972)
		"	Vietnam	Moderate		Ling (1972)
		"	Taiwan	Moderate	200 ha	Chen (1976)
		"	Philippines			Bardach et al (1972)
		"	India	Experimental	---	
A. broughtoni		"	Japan	Moderate	---	Ling (1972)
A. ganosa bisenensis		"	Japan	Moderate	---	Ling(1972)

TECHNOLOGY OF CEPHALOPOD, SCALLOPS AND ABALONE CULTURE

K.A. NARASIMHAM

CEPHALOPODS

Our present knowledge on cephalopod culture is limited to rearing of the squid/cuttlefish from egg to maturity in tanks or ponds and commercial culture is not practised anywhere.

The squid *Sepioteuthis lessoniana* and the cuttlefishes *Euprymna berryi*, *Sepia esculenta*, *S. subaculeata* and *Sepiella maindroni* have been experimentally cultured in Japan (Bardach *et al.*, 1972). The eggs occurring in nature in clusters are separated carefully and stocked at a maximum of $3300/m^2$ in hatching tanks of the size 195 cm x 115 cm x 60 cm supplied with running sea water at a rate of 6 to 7 litres/minute. The eggs are held in the tank in single layers in plastic mesh baskets. During incubation the tanks are kept in the dark to prevent the growth of diatoms or green algae on the surface of the eggs as this interferes with development. With good sea water supply 95% hatching may be achieved. Larvae and young squids are at times obtained by set nets from the wild. These are transported to the hatchery and cultured in glass tanks supplied with running sea water. The larvae take food 16 to 48 hours after hatching and for the next 40 days live on crustaceans like *Mysis*. The initial stocking rate is about 1 squid/5 cm^2 which after about 20 days is reduced to 1 squid/10 to 15 cm^2. Under favourable conditions the young reach 20 to 40 mm length in 30-40 days. During this period live food is essential to get the maximum survival rate of 80%. The 20-40 mm squid are stocked in large tanks or ponds at 30 to 50 g/m^2 and fed on shrimp or pieces of fish. Ideally 8 to 10% of the weight of the squid is to be given twice a day as ration. The experiments suggest that it is possible to rear a 4 g animal to marketable size weighing 500 to 700 g within 5 months.

In the United States of America the squid *Sepioteuthis sepioidea* was successfully reared from egg to maturity in less than 5 months (Bardach *et al.*, 1972). The most crucial factor in its culture is feeding. The best food for the young squid was found to be the mysid _Mysidium columbiae_. A daily ration of about 45% of the body weight of the squid gave conversion ratios of 5 to 10:1. The squid attained a maximum length of 105 mm and 77 g weight in 146 days.

The cuttlefish, _Sepia officianalis_ was reared in open system tanks in France (Richard, 1976). In the tanks the water was oxygenated with air compressors and thermostatic electric heating was used to maintain a minimum of 7°C. A layer of fine sand helped the cuttlefish to hide during day time. The optimal stocking density was less than 1/10 (ratio of animals surface to tank surface). Higher density resulted in growth disparity. The cuttlefish prefer live food. In 1-3 days after hatching amphipodes were given as food and as they reached 2-3 cm length they were fed with shrimps, small crabs and fishes in convenient size. A survival rate exceeding 80% was obtained.

In India experimental culture is in progress at the Regional Centre of Central Marine Fisheries Research Institute, Mandapam Camp to culture the squid _Sepioteuthis arctipinnis_ and the cuttlefish _Sepia aculeata_.

The culture of octopus though attempted in several countries has met with only limited success. At the moment the major constraints for attempting any commercial culture of cephalopods seem to be the cost of feeds, shortage of egg capsules in nature and the difficulty in rearing the larvae.

SCALLOPS

Scallops are one of the most pupular sea foods and are cultured commercially in Japan. The techniques involve spawning and rearing by standard hatchery methods and farming in sandwich cages suspended from raft/rack or culture by long line method. Also the scallops can be cultured in pens close to the shore.

The deep sea scallop, Patinopecten yessoensis is cultured commercially in Japan to a limited extent (Bardach et al., 1972). At Mohne Inlet 1000 litre polyethylene tanks are suspended from a raft in the sea and sea water is pumped to the shore for filtering before being fed to the tanks. As the tanks are immersed in the sea there is no temperature control and hatchery rearing is seasonal, confined to late spring, summer and early fall when the sea water is warm. Solar warming of the circulated water in the tank was found to be adequate to provide the increased temperature for induced spawning. The adults and the larvae reared in the tanks are fed with cultures of unicellular algae grown in the laboratory in enriched media. Organisms now in use include the flagellates Isochrysis galbana and Monochrysis lutheri and the diatom Chaetoceros calcitrans. In the early stages the larvae are fed with falgellates and in later stages with diatoms or a mixture of the two. Also seed from the wild is collected by suspending a variety of cutch materials such as branches of Cyprus, plastic web bags filled with shells etc. The young drifting scallops attach to the collectors by byssus thread (Iverson, 1976). The young seed scallops are grown suspended in the sea from a raft in 0.3 x 1 m rectangular metal frame held in place between layers of loose plant fibre and nylon mesh netting. As the scallops grow the plant fibre is removed from the sandwich frames. Since this method is expensive, alternately, when they reach about 4 cm size they are either planted on the bottom or raised by the long line method (Iverson, 1976). A piece of nylon thread is strung through the 'ear' of the scallop shell and are suspended from a long line tied to a raft. Scallops grown in the sandwich frames and by long line method have reached marketable size of 10-11 cm in 2 years. The cost of labour and materials required are the constraints for expanding the scallop culture on commercial lines in Japan.

Very little success was achieved in the culture of the European scallop, Pecten maximus. In France this species was reared to the veliger stage (Bardach et al., 1972). In the U.S.A. Sastry (1968) has shown that apart from the temperature, food supply is also a controlling factor in gonadal maturation of the bay scallop Aequipecten irradians. By manipulating these two factors he was able to spawn A. irradians out of season. He successfully reared the larvae to sub-adult stage. The bay scallop can be grown to marketable size in pens close to the shore in 9 months (Iverson, 1976). In Russia Mizuhopecten yessoensis and Spisula sachalinensis were cultivated by providing suitable fibrous seed collectors either suspended from a raft at depths of 1-3 m or placed on the bottom (Milne, 1972). The seeds were transplanted to Nylon mesh bags suspended from raft/rack for further growth.

In our country the scallops are not well represented and they neither form a fishery nor cultured at present. They are all generally small except Amussium pleuonectds which occurs along the Orissa Coast (Hornell, 1951).

ABALONES

Among the edible gastropods the abalones have reputation of a gourmet food with fine flavour. They are slow moving herbivores, inhabiting rocky shores. Important abalone fisheries occur in China, Japan, Mexico, U.S.A. and Australia. Their culture has been undertaken only in Japan and California (Bardach et al., 1972). The culture practice involves induced spawning, hatchery production of seed and on bottom culture of abalones to marketable size.

Among the abalones Haliotis discus, H. diversicolor, H. gigantea and H. seiboldi are commercially important in Japan and much success was achieved in the culture of H. discus (Bardach et al., 1972). The abalones mature fast if the water temperature is raised to 20°C. In mature females the gonads are green in colour and milky white in males. Mature males and females at 1:4 ratio are placed in 2 x 2 x 0.5 m outdoor concrete tanks and subjected to thermal shock. From 20°C the water temperature is raised by 3 to 7°C for 30 to 60 minutes and brought back to original temperature. If need be the procedure is repeated. Also a short exposure to air which is warmer than water or an abrupt change in the pH were also known to induce spawning.

The fertilised eggs are placed in deeper tanks, of size 2 x 1.4 x 1.4 m at a density of about 1,00,000/tank for 8-11 days to complete the larval stage. The water in the rearing tanks is not changed and the swimming larvae either feed on natural plankton available in the tanks or are provided with specially cultured flagellates and diatoms. When they are ready to metamorphose and settle, 50 cm square corrugated plastic sheets previously immersed in running water to develop a film of benthic diatoms are placed vertically in the tanks. Once the abalone have settled on these collectors they are placed in 10 x 10 x 2 m outdoor tanks supplied with running sea water. In each tank 1000 collectors, each with approximately 10,000 abalone are placed. Until they reach a length of 2-3 mm, diatoms serve as food and later fed with soft brown alga, Undaria sp. every 2-3 days. Undaria is often scarce and finely chopped pieces of green alga Ulva or artificial diet comprising protein in insoluble calcium jel is substituted. Survival from larvae to juveniles suitable for stocking is only about 1% and the poor survival is believed to be due to lack of food, particularly soon after settling. In Japan hatchery production of young abalone for stocking is estimated at 10,000,00 per year and 10% survival was obtained after stocking in the farms. Market size is generally reached at about 4 years when they are about 15 cm (Iverson, 1976). H. discus was experimentally grown in off bottom cages made of plastic waste baskets covered with cloth netting and suspended in the sea from a raft. They are stocked at 5 mm length, fed on Ulva and Laminaria until they reached the marketable size of 10 cm in 4 years.

In California, USA the red abalone Haliotes rufescens is being cultured (Bardach et al., 1972). The tank method of spawning followed in Japan was most effective. Feeding the larvae is problematic and in a month it reaches 5 mm in length with a survival rate of 10-20%.

Spawning, larval rearing and growing the seed upto 30 mm length takes one year and is done in indoor tanks. They are transferred to outside reservoirs for further growth. At various stages of culture they are fed on a variety of algal species and supplied with sand filtered sea water. The major constraints for intensive abalone culture are to provide suitable food at different stages, particularly to the juveniles and the slow growth of the abalones. The Japanese found that young abalones grow 4 to 5 times faster in warm water from coastal power stations than those grown in natural habitat (Iverson, 1976).

In India the abalones do not form a fishery and their culture is not yet attempted.

SEED PRODUCTION AND HATCHERY DEVELOPMENT

K. ALAGARSWAMI

It is fundamental to culture of any aquatic organism that the right type of seed is available at the right time. Man, from the time he developed aquaculture interest, has depended on the seed available in the wild for stocking the farms and even today this dependence is absolute in most cases. However, techniques have been evolved for "catching" the seed on collectors or cultches to reduce labour, to ensure quantity and to increase operational efficiency. But fluctuations are common upsetting the plans of the culturists.

During the last two decades, tremendous interest has been generated in the field of artificial breeding of molluscs, following the success of Dr. Victor Loosanoff and his colleagues at the Milford Laboratory in the U.S.A. in the early sixties. This has led to the establishment of commercial hatcheries, particularly in the U.S.A., for oysters and clams.

SEED PRODUCTION IN NATURE

Reproductive strategy

The general reproductive strategy of molluscs, particularly the bivalves, is the production of a large number of eggs, in millions, external fertilisation, a pelagic phase of the larval stages and ultimate settlement of the young ones in suitable substratum. The American oyster Crassostrea virginica releases an average 54.1 million eggs and the clam Mercenaria mercenaria discharges an average 24.6 million eggs. The mortality rates at different stages of the development are so high that the number of viable young ones finally settling on the beds is very very low. The very high fecundity is nature's mechanisms for the propagation of species against all odds of a dynamic environment. The fertilised eggs pass quickly through the early developmental stages and reach the typical veliger stage within 24 - 48 hrs when the larvae are able to feed upon microalgal food in the environment. The veliger subsequently passes through umbo and other stages before they metamorphose to the young stage closely resembling the parent and settle down on the substratum. The term "spat" is used to denote the stage at settlement in the case of species such as oyster, pearl oyster and mussel where the young ones attach themselves permanently or temporarily as the case may be to the substratum with cementing substance or byssal threads. It is seen generally that the areas suitable for settlement of spat are not always good for growth of the molluscs. This had led to the development of exclusive seed collection centres and production centres in many cases. For example, in mussel farming in France, the seed collection centres are located in the southern France in La Rochelle, whereas the production centres are in the north coast of Brittany.

Seed collection

Most of the aquaculture systems are semi-culture systems in the sense that seed is collected from the wild and transplanted in suitable areas for achieving higher and quicker yields through manipulation of the culture system. Several methods have been developed for the collection of spat of molluscs.

a) Ceramic tiles: Perhaps the earliest and efficient collectors of spat of oyster *Crassostrea angulata* were developed in the Bay of Arcachon. Slightly curved ceramic tiles are used as collectors (cultches). They are first thinly coated by bathing them in a mixture of lime and water. The treated tiles are piled up in crates and laid in the spat collection beds. The spat can be easily removed from the tiles which are used over and over again. The tile collectors are used extensively in European oyster culture with subtle variations.

b) Shells: The use of molluscan shells as collectors of spat is highly developed in the oyster culture industry of Japan. Scallop shells are strung on galvanised wire and are suspended as "rens" from racks. A good set is considered to consist of about 200 spat per shell of which 50 - 60 survive to the seed oyster size of 1 to 1.5 cm. The shells of oysters and mussels either broadcast on the bed or placed in bags are used as collectors of oyster spat in Europe, U.S.A. and Japan. Shells of mussels are spread on the bottom in the Oosterchelde of the Netherlands for the collection of spat of oyster.

c) Ropes: Ropes are standard spat collectors in mussel culture in Spain and France. Loosely woven and heavily tarred ropes of 12 - 15 mm diameter are suspended from rafts or racks. Although natural fibres such as coco and esparto grass ropes are in use, these are being fastly replaced by non-toxic synthetic ropes.

d) Poles, racks, sticks, twigs etc: These wooden structures are commonly used for the collection of oyster spat in Japan and Australia. Rows of poles called "Bouchots" are used for the collection of mussel spat in France. Cedar springs are extensively used for the collection of pearl oyster spat in Japan. Branches of red mangrove and wooden planks coated with bitumen are used for the collection of mangrove oyster spat in Venezuela and Cuba. Split bamboo frames have proved very successful for the collection of Pinctada margaritifera seed in Dongonab Bay in Sudan.

e) Plastic meshes: Rubber-like plastic net material called "Netron" is gaining importance as collector of oyster spat in Japan although it is about five-times costlier than shell collectors. Plastic sheets of 3 mm thickness made of polyethylene or poly-propylene have shown promise for the collection of oyster spat. The French oyster culturists have tried rubber-like plastic mesh material, of the sise and shape same as that of ceramic tiles, coated with cement but have found it uneconomical.

f) Others: Cement-coated egg carons have proved successful as oyster spat collectors in Prince Edward Island. Coconut shells are also used as cultches in some cases.

g) Collection of clam seed: The clam seed are collected using fine mesh wire scoops. The density of seed population of Anadara granosa is as high as $10,000/m^2$ or more in the Malaysian beds.

h) Cultchless spat:. A more recent development in hatchery production of oyster seed is the cultchless spat. Calcium carbonate particles are used for collecting the spat. When spat settle on plastic sheets they can be removed. These free spat are desired for growing regular shaped oysters for market.

Factors deciding successful seed collection

Besides employing suitable cultches for the collection of seed, several factors decide the success of seed collection. The areas for good spat settlement should be identified. In many parts of the world only a small percentage of oyster beds are suitable for spat collection. The timing of laying the collectors is very crucial. If the collectors are laid a little too early, settlement of barnacles and other fouling organisms will take place and the collectors will not be useful for seed collection. If they are laid late, they will miss the spatfall. In all commercial seed collection operations such as the oyster seed collection in Gulf of Morbihan in France, Long Island Sound in U.S.A. and Miyagi Prefecture in Japan, the Government biologists monitor the abundance of planktonic larvae and guide the farmers on the time for laying the collectors and predict spatfalls. Another crucial factor is the level at which the spat collectors are suspended. This depends on the layer where most of the advanced stage larvae of the particular species are found. This would also enable avoiding layers susceptible for barnacle settlement.

Seed trade

The seed collection and supply has developed into an industry as such. Generally those engaged in culture for production are not involved in seed collection and they purchase seed for planting in the farm.

International seed trade has also become popular with the introduction of species native to a region to other areas. The Pacific oyster Crassostrea gigas has been introduced along the Pacific coast of U.S.A. and Canada and in Spain and France. The Japanese culturists grow spat on oyster shells as required by their foreign buyers and ship them to those countries. This has led to introduction of pests, predators and parasites also to the new areas with the attendant problems of control.

HATCHERY PRODUCTION OF SEED

Interest in the artificial breeding of oysters dates back to the eighties of the nineteenth centry. W.K. Brooks of John Hopkins University had in 1880 worked on the development of eggs and early larval stages of the American oyster Crassostrea virginica and J.A. Ryder in 1883 and F. Winslow in 1884 made an unsuccessful attempt to bring oyster larvae to metamorphosis. It is in 1920 that W.F. Wells of the New York Conservation Commission succeeded in rearing the oyster larvae to setting which opened the door for further development in this direction. Wells also succeeded in rearing the larvae of the mussel Mytilus edulis, the clams Mercenaria mercenaria and Mya arenaria and the scallop Pecten irradians. His method which is popularly known as Wells-Glancy method used the food naturally present in the sea water for the rearing of larvae and naturally spawning adults were used as parents.

In the mid-1940s Dr. V.L. Loosanoff, H.C. Davis and other colleagues in the U.S. Bureau of Commercial Fisheries Laboratory at Milford, Connecticut, U.S.A. developed techniques for induced spawning and rearing of larvae using laboratory-reared algal culture. Subsequently the Milford team developed techniques for out-of-season maturing and spawning of a number of commercially important molluscs; production of selected micro-algal food for the larvae; and disease control. The hatchery technology of this team is known as the Milford method.

These developments have lad to the establishment of commercial hatcheries along both the Pacific and Atlantic coasts of U.S.A. and the Maritime Provinces of Canada. The hatcheries are so versatile that they can switch over from the production of seed of oyster to that of clam or abalone.

Model operation of commercial oyster hatchery

- Selection of mature oysters based on size, shape and growth rate.
- Hold at 10°C in the hatchery.
- Condition for spawning by slowly raising the temperature to 18°C or more.
- Hold the oysters at the above temperature for 2- 4 weeks.
- Induce spawning of oysters in glass trays by raising temperature to 25°C.
- Spawning and fertilisation.
- Transfer fertilised eggs to 120-gallon conical rearing tanks.
- Larval development.
- Grade larvae by screening. Retain only those above 0.3 mm (20%) and discard others (80%). This step is to select only the fast growing ones.
- Transfer selected larvae to Larval Rearing Tank. Sea water pumped from the bay and centrifuged to remove larger plankton. Water carrying only small algal cells suitable as food for oyster larvae is stored in 20,000 litre tanks in greenhouse. Algae allowed to grow for24 hours. If numbers are insufficient, 200-litre algal culture is inoculated. The resultant culture of microorganisms is used to fill the Larval Rearing Tanks.
- Larvae ready to set after 10 - 15 days.
- Transfer to Settling Tanks.
  Each plastic settling tank of 3600-litres capacity contains 10 bushels (1 bushel = 35.2 litres) of specially selected oyster shells spread at the bottom.
- Setting occurs in 24 - 48 hours.

- Transfer shells with spat to Nursing Tanks.
  The Nursing Tanks of 27,000-litres capacity each are located in a greenhouse and supplied with water containing algal bloom. Shells with spat are transferred to half-bushel plastic mesh bags and 200 such bags are suspended in the Nursing Tank from wooden beams.

- Maintain spat in Nursing Tanks for 4- 7 days or more.

- Transfer wooden beams with shell bags by chain-hoist and overhead rail to floating rafts moored outside near the dock.

- Spat reach fingernail size (1 - 2 cm) in 2 - 3 weeks.

- Plant the spat on the oyster beds.

  Total duration of hatchery operation is 4 - 6 weeks.

Basic requirements for hatchery production

Controlled spawning: Techniques for the controlled reproduction of the species must be available. The Milford Laboratory has developed techniques for maturation of gonads and spawning of several species of bivalves at any part of the year irrespective of the reproductive condition of the organisms under wild conditions. Several methods have been developed for the induced spawning of molluscs. The commonest technique is conditioning the molluscs for accelerated development of gonad through thermal stimulation and spawning them by a quick rise in temperature to the optimum level and adding egg or sperm suspension. This method has been particularly successful for the species in the sub-tropical and temperate regions. The Japanese workers have mostly relied on chemical stimulation for spawning molluscs. The methods include spawning the animals in ammoniated sea water or injection of neutral potassium salts or ammonium hydroxide. Stripping the gonad and treating the eggs with a weak solution of ammonium hydroxide also gives good results in some cases. Methods such as giving a mild electric shock and pricking or severing the adductor muscle have proved useful for spawning the mussels. Addition of hydrogen peroxode to alkaline sea water has been effective in a number of molluscs including abalones. Thus a range of physical, chemical and biological induction methods are available for spawning the molluscs and those suitable for particular species should be developed.

Water quality

Water quality is one of the critical factors in determining the success of hatchery production of seed. Temperature, salinity and pH must be maintained at the required level. Water should be relatively pure from pollutants, particularly metallic salts, pesticides and detergents. Silt will have an adverse effect and should be removed by filtration. The water should be treated with antibiotics, sulpha drugs or untraviolet radiation. Areas where intensive algal blooms appear frequently should be avoided.

Larval food

Food for the different stages of larval forms is another important aspect of hatchery operation. The right type of food in right concentration should be supplied. The algae must be of size suitable to be consumed by the larvae and must not have a cell wall and must not produce toxic metabolites.

Disease control

Cleanliness of all tanks, utensils and other materials should be maintained regorously. Growth of pathogenic bacteria, fungi, ciliates etc. should be controlled. To a large extent these could be controlled with antibiotics, sulpha drugs and ultraviolet treatment of incoming sea water.

Closed cycle shellfish factory

Success in commercial hatchery operation has led to the concept of controlled culture of the full life cycle of the molluscs. A closed cycle shellfish factory is being tested at the University of Delaware in U.S.A. for production of oysters and clams from egg release to market size. Although technical feasibility has been established, a substantial amount of research and development is yet to be done to make the project economically viable.

LARVAL NUTRITION

Larval nutrition has received much attention simultaneous with the development of hatchery techniques. The stored food in the fertilised eggs lasts only for a few hours and thereafter availability of appropriate food decides the growth of the larvae. Live algal food has been found to be the best for the larvae of most of the molluscs studied. But certain species of algae produce metabolites toxic to bivalve larvae and they should be avoided. Those which contain a cell wall are also not so suitable as food of larvae. The naked flagellates Isochrysis galbana and Monochrysis lutheri have been found to be exceptionally good for oysters and clams. The food value of microorganisms also depends, in part, upon how completely they meet the food requirements of larvae. It has been found by several workers that a mixture of suitable species such as I. galbana, M. lutheri, Platymonas sp., Dunaliella euchlora, all naked flagellates, induce better growth rate of larvae than when they are used singly. The feeding density varies from 5000 to 15,000 algal cells per larvae twice a day.

Dried algal food has been used successfully in the case of some species of oysters but has not been useful in most other cases. Artificial feed preparations have also not been useful.

The success of larval food production in hatcheries is often dependent on an adequate supply of good stock cultures to ensure continuance of the strain and consistent results. Stock cultures are best maintained in small volumes of an enriched sea water medium. Several media for algal culture have been developed by scientists and composition varies based on the requirements of algal species. Convenient culture vessels are 120 or 150 mm screw-capped test tubes filled with 10 ml of media or 125 ml screw-capped flasks filled with 60 ml of media. Cultures may also be maintained in solid media, such as sea water agar slants.

Pyrex carboys of 20-litre capacity or more are used for culturing foods either in batch or semicontinuous culture. The advantages of this size vessel are that moderately large volumes of several species can be made simultaneously available and that cultures may be discarded if they are not satisfactory foods. In semicontinuous culture, the cultures are harvested as needed and volume removed is made up with sterile media. Where extensive hatchery operations are carried out, a much larger volume of food may be needed and outdoor tank culture is resorted to. In open tank culture complete control of the system is not possible. Mass culture of algal food is one of the essential functions of the shellfish hatcheries. While the stock cultures and carboy cultures are done under illumination from flourescent lights, tank culture is done in greenhouses.

GENETIC IMPROVEMENT OF STOCKS

Studies on the genetic resources of the cultivable species, particularly the American oyster C. virginica, Pacific oyster C. gigas and the quahog clam M. mercenaria have received some attention and cross-breeding has been experimentally successful. But a lot of work remains to be done yet in this field for upgradation of stocks. At the Virginia Institute of Marine Sciences, strains of oysters which are resistant to oyster-diseases have been developed using the survivors of the Chesapeake Bay disease as parents. The Oyster Research Institute at Kesennuma, Japan, has carried out extensive cross-breeding experiments on oysters. Hatchery production will become truly beneficial when our knowledge on the genetic resources of the cultivated species of molluscs has improved and practical application becomes possible for evolving strains or upgrading stocks with desirable characteristics.

Men's increasing interference with the foreshore environment and the estuaries for recreational, industrial and other purposes is affecting the ecosystem of natural production of molluscs. Dependence on nature for seed requirements will be more and more unpredictable in future. Hatchery production of seed will gain further importance and will perhaps be the only means of sustaining culture operations in the distant future.

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SHELLFISH DESEASES AND THEIR CONTROL

S. MAHADEVAN

The problems confronting the fish farmers are experienced by shellfish farmers also in the matter of diseases amongst the tended stock although the nature of diseases vary. Shellfish culture in India is in the nascent stage and disease problems have not so far posed problems. But in order to put the farming system of oysters, mussels and clams on sound footing it is ncessary to understand the common diseases and causes of the diseases amongst shelled forms facing the shellfish farmers in other countries.

Sinderman (1970) gives an exhaustive review of the 'diseases of shellfish' although in recent years Leibovitz (1978), Farley (1978), Sprague (1978), Cheng (1978), and Sinderman (1978) have added considerably to further the knowledge on the subject. Much of our knowledge concerns species of economic importance. Microbial pathogens that have been implicated in mass mortalities include bacteria, fungi and protozoans. Several parasites have been found to be pathogenic under specific environmental conditions. Most of the commercial bivalve molluscs occur ofter intertidally in shallow inshore waters. Unusual mortalities due to diseases appear to be more in these habitats than in offshore populations. Information on oyster diseases is more abundant than that on mussel, clam pearl oysters, scallop and abalone. This is partly due to the worldwide economic importance of oysters.

In culture system and natural beds direct threats to productivity is posed by the biological environment. The detrimental effects of cohabiting organisms fall into three basic categories (1) predation, (2) competition and (3) disease and parasitism.

PREDATION AND COMPETITION

Predation is less of cultured organism to other creatures preying upon them for food. Limited predation can weed out diseased members of a crop thus controlling infections. The predators of of sessile organisms are various species like sea-stars, octopi, fishes and rays, gastropods, crabs and some birds. Asterias rubens and A. forbesi kill young oysters in European countries. The shore crab Carcinides maenas, red crab Cancer productus, Murex erinaceous, Thais lamellosa, Polynices lewesii, Tritonalia japonica, Octopus vulgaris, Pagrus pagrus, Myliobatis aquila and the flat worm Stilochus pilidium are known predators in many oyster farming areas. Particular damage is done in the spat stage when spat are transplanted. In India, the gastropod Cymatium pileare is known for its predatory feeding of oyster spat. Hand removal is the best method to eliminate them. Similarly the green crab Scylla serrata feeds on young oysters.

Hand picking of predators, transfer of oysters to low saline waters or saturated saline media for a limited duration, trapping etc. are some of the methods adopted to eliminate predators. In Europe and U.S.A. dredges, mops and quicklime spreading over the beds are being used to control them. Removal of culture stock from natural predator range seems likely to be an effective measure for protection against demersal fishes, octopi and crabs as well. Birds do not pose much problem. Free swimming predators like marine mammals, rays, carnivorous fishes, octopi and squids have a wide diet range. Control through aggression suppressing pheromones (chemical signals) is now advocated in large-scale culture. Intra culture predation may be controlled by adequate feeding and provision of defensible niches. Mesh barriers, air barriers, electrical barriers for repulsion, accoustical barriers, chemical controls (pheromones to affect social, feeding behaviour) in fishes and animate barriers are some of the ways being devised at present.

Competition is defined as rivalry between cultured organisms and uncultured organisms for any environmental resources that may be limiting, thus tending to reduce cultured organisms' productivity. If little is known in mariculture about predation nothing is known about competition problems. When competitor forms are similar to cultured forms they can be allowed to coexist if cultured productivity degeneration is not serious. In the case of phytogenetically dissimilar forms to cultured forms, biological controls such as diseases and parasites might prove effective in controlling their numbers. Chemical control is also suggestible. All these show the obvious need for comprehensive empirical investigations of the whole spectrum of questions implied by predation and competition.

In oysters and mussels the foulers and epibionts pose problems. Ascidiella, Botryllus, Ciona settlement oust the spat settlement and cause poor growth and mortality. D.D.T. dissolved in oil is sprayed on tiles or spat collectors to ward off these. 300 ml of fluid containg 2% JEZO which consists of 20% D.D.T. in oil with a detergent is used effectively. The slipper limpet, Crepidula fornicata (cup) competes for space with oysters in Holland. Hand removal of this is resorted to during nights. In Colpomenia sinuosa called "oyster thief" which smother the oyster spat by profuse overgrowth Perwinkle control by Littorina littorea helps Sea lettuce, Ulva lactuca also growing on oyster cages or beds creates anaerobic conditions. Schizoporella (Bryozoan) an epibiont creats problems in French coast. These are periodically scraped. Diplostoma listerianum a synascidian is weeded out by prolonged immersion of oysters in a solution of brine or in freshwater. Modiolus phaseolinus, the horse mussel, competes for space in Norway. These are difficult to control but due to manual operations these are removed. Similar problems in Indian coastal waters can be solved by developing local measures.

DISEASES

The diseases may be classified broadly into (a) infectious, (b) parasitic, (c) non-communicable and unknown etiology. Parasitic infestation may be endoparasitic or ectoparasitic. Infectious diseases are caused by viruses, bacteria, fungi, protozoans and less commonly by algae. Other causes of debilitation and mortality include deficiencies, wounds, poisons, environmental factors etc.

Microbial diseases of viral, bacterial, fungal and protozoal etiology tend to destroy the tissues of the host and multiply within the host. The pathology depends on intensity of dose, resistance of individuals, infective dose, environmental variables and host nutrition. The effect may be from chronic to acute afflictions leading to mortality. Viruses are known etiological agents for fibro epithelial tumour. Baculovirus, reolike virus (RLV) causing neurological damage, herpes like virus (HLC) damaging hemocytes and picarnolike virus (CBV) afflicting epidermal tissues, cause serious damage to the stock. Bacterial disease caused by Vibrio (Vibriosis) also leads to mortality. Pseudomonas, Mycobacterium, Myxobacterium, Chondrococcus and Aeromonas are also known to affect the farmed stock seriously. Most of these bacteria present in sea water or on the surface of fishes invade and cause pathological effects if hosts are injured or subjected to severe environmental stress. Protozoa and cnidospora are among the best known serious pathogens of marine fishes and shellfishes. Haemoflagellates, ciliates, myxosporidia, microsporidia and coccidia bring out severe effects on hosts causing nerve and gonad degeneration and castration. Parasitic diseases are caused by Helminths (Trematodes, cestodes, nematodes and acanthocephalans) and parasitic copepods. Helminths as larval infection are of great significance. Growth retardation, tissue disruption, metabolic disturbances and mortality of hosts in serious infections are characteristic of helminth invasion of the host. These invariably weaken the host and help the entry of secondary invaders leading to mortality. Table 1 gives a compilation of various diseases among shellfishes reported from all over the world and the organisms causing the diseases.

Disease agent	Host	Effect	Area from where reported
1.	2.	3.	4.
I. Oysters:			
(a) Bacterial:			
1. gram negative motile bacillus Achromobacter	C. gigas	Large-scale mortality (focal necrosis)	Japan
2. gram positive bacillus	"	Multiple abscesses (focal necrosis)	Japan, Maryland & Willafa Bay USA
3. Aeromonas sp.	Larval & juveniles of C. virginica O. edulis	Mortality	-
(b) Fungal:			
1. Dermocystidium marinum	C. virginica	Mortality	Atlantic coast, Gulf coast of USA.
	O. frons	"	Florida
	O. equestris	"	Texas
	C. rhichophorae	"	Peurto-Rico
	O. edulis	"	Holland
2. Monilia sp.	O. edulis	Mortality by 'shell disease'	Holland France
	C. angulata	"	U.K.
3. Ostracobiabe implexa	C. virginica	Mortality	USA
4. Myotomus ostrearum	O. edulis	Mortality 'foot disease" (Maladie du pied) (Muscle atropy)	France, Europe
	C. virginica	"	USA
	C. gryphoides	"	India

1.	2.	3.	4.
5. Cladothrix dichotoma	O. edulis	Mass mortality	West Europe
6. Nocardia sp.	"	"	
7. Actinomycete (sp-?)	C. virginica C. angulata	? ?	USA France
8. Sirolpodium zoopthorum	Juvenile oysters	Mortality	USA
(c) Protozoa:			
1. Minchinia costalis	C. virginica(?)	Mortality (sea-side organism disease)	N. America east coast, Maryland, Virginia, Delaware Bay
2. M. nelsoni (MSX) (haplosporidian)	C. virginica	Mortality (Delaware Bay disease)	North Carolina, Delaware Bay, Chesopeake Bay
3. Chytridispsis ovicola (haplosporidian)	eggs of O. edulis	?	France
4. Nosema dollfusi (microsporidian) hyper parasite)	C. virginica	Mortality believed to cause extensive maortality but later found to be only affecting the quality of meat	USA
5. Nematopsis ostrearum (gregarine).	C. virginica		Virginia
6. N. prytherchi	"		Sonisiana
7. Hexamita nelsoni (flagellate)	O. edulis	Mortality 'Pit disease'	Holland
	O. lurida	Only diseased condition	Washington
8. Sphenophyra sp. (ciliate)	C. virginica	disease	Maryland
9. Orchitophyra stellarum	C. virginica	Gonad atrophy	Canada
10. Ancistrocoma pelseneeri	C. virginica	Disease of dig-tract	Atlantic coast & Gulf coast of USA

1.	2.	3.	4.
11. Vahlkampfia calkensi (=Flabellula calkensi)	C. virginica	Disease of dig-tract	Atlantic coast of USA
12. V. patuxent (amoebas) (=F. patuxent)			
(d) Helminths:			
(i) Trematoda			
1. Bucephalus haimeanus	O. edulis		Mediterranean sea
2. B. cuculus	C. virginica		
3. B. longicornutus	C. virginica	Retards growth	USA (S.Carolina)
	O. lutaria	Mortality	Newzealand
	O. gigas	?	Pacific coastal areas
4. Bucephalopsis haimeanus	C. madrasensis	Gonadal atrophy	India
5. Gymnophalloides tokiensis	C. gigas	Reproduction retarded	Japan
6. Proctoeces ostreae	C. gigas	"	Japan
7. Acanthoparyphium spinulosum	C. virginica	?	Texas
(ii) Cestoda:			
1.Tylocephalum sp.	C. virginica	?	Hawai, Florida, North Carolina
	C. gigas	?	Japan, Taiwan
	P. fucata	-	India, Ceylon
(e) Gastropod parasites:			
1. Odostomia bisuturalis	C. virginica	Deformity;damage and rarely death	USA
2. O. eulimoides	O. edulis		UK
3. O. impressa	C. virginica		USA

1.	2.	3.	4.
(f) Crustacean parasites:			
1. Mytilicola intestinalis	C. gigas	Poor condition index	Japan
2. M. orientalis	O. lurida	-	
II. Mussels:			
(a) Microbial deseases:			
1. Chytridiopsis mytilovum haplosporidian	Mytilus edulis	Eggs affected	West North Atlantic
	M. galloprovincialis	"	Mediterranean (Gulf of Naples)
2. Haplosporidium tumefacientis	M. californianus	Digestive gland enlargement	California
3. Nematopsis schneideri	M. edulis	Gill disease	France
4. N. legri (gregarine)	M. galloprovincialis	"	Italy
5. Ancistrocoma pelseneeri	Mytilus edulis	?	Baltic sea area
6. Kidderia mytili	Mytilus edulis		
7. Ancistruma mytili			
8. Hypocomides mytili (ciliates)			
(b) Helminths:			
1. Diastomum somateriae	M. edulis	Pearl formation	U.K.
2. D.margaritarum	"	"	French coast
3. Cercaria tenuans	"	Orange sickness of mantle	U.K.
4. Cercaria milfordensis	"	" (at times lethal)	U.S.A.

1.	2.	3.	4.
C. Crustacean parasites	M. galloprovincialis	Intestine disease & mortality	Mediterranean
1. Mytilicola intestinalis	M. edulis	"	Germany, Holloand, Spain
2. M. perrecta	Modiolus sp.	-	U.K. Mexico
III. Clams:			
(a) Microbial disease:			
1. Dermocystidium	Donax sp.	Mass mortality	California
2. Hyaloklossia pelseneeri (Coccidian)	Tellina sp.	Kidney infection	Europe
3. Pseudoklossia glomerba	Tapes floridus T. virgeneus	Mild infection	Mediterranean
4. Nematopsis sp.	Solen vagina	Mantle disease	France
5. N. schneideri	Cardium Mactra Donax vittatus	Gill desease	France
6. Trichodina myicola	Mya arenaria	Palp affliction	California
7. Ancistrocoma myae	"		California, Massachuchetts
(b) Helminths:			
1. Himasthla larvae	Mya arenaria	Gill disease	California
2. Gymnophallus larvae	Mya arenaria		"
3. Postmonorchis donacis	Donax sp.		"
4. Anabothrium sp.	Gaper clam	Foot disease	Pacific coast of USA
5. Echeneibothrium sp.	Venerupis staminea	Tissue infection	California

1.	2.	3.	4.
(c) Crustacean			
1. Mytilicola mactrae	Mactra veneriformis	Tissue infection	Japan
2. M. perrecta	Mercenaria mercenaria	?	Mexico
IV. Scallops			
1. Pseudoklossia pectinis	Aequipecten maximus	Kidney infection	France
2. Nematopsis duorari	A. irradian	?	Florida
3. Paranisakis pectinis (now confirmed as Sulcascaris sulcata)	A. gibus A. irradians	Visceral mass disease	Florida
4. Odostomia seminuda	Calico scallops	Visceral mass damage	East coast USA
5. Boring sponge ?	Placopecten sp.	Shell damage poor yield of meat	Canada
V. Pearl oysters:			
1. Muttua margaritiferae	Margaritifera vulgaris (=Pinta fucata)	Gills	Ceylon
2. Musalia herdmani	"	"	"
3. Bucephalus margaritae	Pinctada martensi	Gonad	Japan
4. Echinocephalus uncinatus	P. vulgaris	Adductor muscles	Ceylon
		Gonadial affliction	Japan

Although remedial and curative measures have been taken to contain and eliminate the disease factors universally applicable methods are yet to be publicised. In the case of fishes, drugs used and their administration to treat certain diseases have been given by Amlacher (1970). It is of great importance to bestow attention to acquire specialised training in diagnosis and develop extension services for field application. A regional training programme is of high priority.

HARVESTING: TECHNIQUES OF HARVESTING
POST HARVEST TECHNOLOGY

S. MAHADEVAN

Fishing industry has been developing equipment and techniques for open sea harvesting for centuries. Harvesting in mariculture operations, coastal as well as open sea, should pose fewer problems than are found in naturally occurring stocks. Particularly so if the crop is sessile. The general principle underlying harvest is that the system should provide harvest of crops at the optimum point in the growth cycle, (i.e) the stage at which the ratio of rearing cost to marketing return is most favourable to culturist. The system should aim to transfer the harvested crop to the on site processing centre or marketing facility without significantly degrading the quality of the product. The effort in harvest should concentrate and harvest on a very high percentage of the crop intended for harvest. Unharvested material will be wasted and therefore affect the cost effectiveness of operations adversely. Harvesting system should be a non-labour-intensive work; bringing down capital and operational cost. It should also be so designed that it is done at rates that are compatible with on site transport to market disposal or harvest-processing rates so as to maximise capital equipment utilization and minimise temporary storage requirements. Cultured crops are mostly homogenous in species and size and therefore all the produce will be easily marketed without rejection for want of quality level.

Sessile organisms like molluscs attach themsleves or remain on some firm substrate. The harvesting system must remove them from the substrate without damage. The substrate thus becomes a part of the harvest strategy for easy removal and reutilization. At present oysters and mussels are the only molluscs cultured extensively. Mussels are grown in ropes and oysters are reared on cages, trays, racks, longlines, poles or sticks. At harvest the tended stock are removed individually and transferred to shore. Once open sea culture is successfully taken up and ropes of greater length are going to be employed for greater yield it is going to pose problems in lifting them manually and removing the mussels individually. Similar situation in line culture of oysters in deeper areas in Japan and Pacific region has been effectively carried out by Winches being employed to haul the ropes which are heavy due to oysters grown on them. In mussel culture also similar device is best employed to great advantage over the comparatively labour intensive practice in use. Removable growing racks are advocated in open sea culture in future for oyster growing. These can be used to grow oysters on both sides of rack and a mechanised removal by drawing the rack through closely spaced scraper blades will yield good results. Coating the surface with a material that could be peeled off at harvest taking the attached molluscs with it is also another alternative.

Harvest utilization

In coastal aquaculture shipboard installation for processing the raw material is dispensed with since the harvested product can be quickly transferred to shore without causing degradation of the flesh. The products harvested are transhipped to markets and disposed of fresh in the case of local markets. Where the markets are interior or in a far off place involving long duration journey by van or rail precautionary steps are to be taken to retain the wholesome nature of flesh.

Canning and freezing are two processes that are found useful in this. After shucking oysters or removal of mussel shell the flesh is suitably preserved.

Depuration

Marine bivalves such as oysters, mussels and clams are some of the shellfishes much relished. These being sedentary and growing so close to the shore are susceptible to sewage and other contamination. As they are filter feeders they may accumulate bacteria, virus or fungal pathogens in their body which may create nuisance to the persons eating the meat. Under certain conditions biotoxins, pesticides and heavy metals may also be absorbed by their tissues. Hence before consuming the flesh a high purity of these is essential before they are marketed. Commercial producers practise purification techniques but these differ from country to country. Simple washing in chlorinated water to exposure to ultra violet ray treatment and ozonisation method are adopted. Cleaning of bacteria contaminated oysters using their own physiological filtration was developed at U.K. Wells (1923) described a purification plan using chlorinated seawater. This method is still in vogue in many developed countries. Ultra violet sterilization has recently superceded this method. Coliform are eliminated to 99.9% by this method.

A simple purification system adopted and advocated is as follows:

Seawater is pumped into a sump and to a sedimentation tank of 4 chambers 1 m x 1.5 m x 1.2 m each. The water passes through these to filter bed thus reducing silt materials. All suspended particles and silt are effectively removed by sand filters in this tank (1.8 x 1.8 x 1.2 m). The water passes on to a ground level storage tank of 10,000 litre capacity.

Three tanks of 2.5 x 2.5 x 1.0 m get separate channels of supply from sump and separate drainage provided for each. The drainage valve is 50 cm high from bottom of tank so that 50 cm water column can be always maintained. The horizontal link is plugged while tank is used for cleaning and   to drain water completely. Water jet is given to these tanks by pumps.

Oysters placed on wooden grids are lowered in one of these tanks in nylon knitted trays. Oysters are hosed throughly by strong seawater jet to remove external mud and dirt. Filtered seawater is filled in the next tank to 50 cm height to which the oysters from the first tank are then transferred and allowed to remain for 12 hrs. The bacteria are eliminated here by natural physiological process. The water is later drained and a strong jet of water is hosed on oysters to clear faeces and pseudo faeces on the oyster shells. The tank is refilled with water and the cleaned oysters are left there for another 12 hrs. At the end of this they are kept for one hour in freshly chlorinated water with 3 ppm chlorine. They are later dechlorinated by hosing filtered sea water and placed in a holding tank before disposal.

Though the need for depuration was felt even in very ancient times, even as recent as 1978, oysters were being exported without purification (Anon, 1978). Most of the countries wherein oyster is being cultivated at present in large quantities enjoy cold climate. In Europe and North America the temperature of seawater falls at times below 10°C and purification process in abnormally prolonged for 3 to 5 days irrespective of the method viz. chlorination, U.V. radiation and ozonisation, because of the slow filtering activity of the oysters at such low temperatures. This has been overcome by using heat exchangers to keep the water at elevated temperature, thereby making the process expensive. In Japan, possibly with a view to reduce the cost of production, the shucked oyster meat is chlorinated before being canned (Korringa, 1976). The Australian growers have found relaying the sewage contaminated oyster in clean marine area for a period of at least seven days, a more efficient method of depuration than cleaning them in tanks (Anon, 1977). Under certain circumstances even seven days may not be sufficient. Further studies conducted therein have shown that reduction in bacterial contamination in sewage effected oysters could be effectively done by freezing and keeping the oyster meat at -23°C for seven days (Anon, 1977, Quadri et al., 1976). In tropical countries our seawater is warmer and depuration takes only a few hours although the chlorination method of depuration of shellfishes is followed at present. It is intended to use a suitable ultraviolet steriliser to achieve maximum hygeneic standard of the products making it more safe for counsumption.

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PROCESSING, PRESERVATION AND MARKETING

K. NAGAPPAN NAYAR

Shellfishes (Bivalves) are highly perishable and this irrespective of their market potential is a major hurdle to the development of the industry. Soon after spawning the meat will be thin and not very tasty. Therefore during the breeding season they are not marketed. The consumer's food preference also affects the market. In France fattened oysters having green coloured meat due to overfeeding on rich algal bloom are highly priced and in much demand.. For this before marketing the oysters are grown for a short duration in special nutrient enriched ponds. In America such oysters are not favoured and does not find a place in the cosumer market. In most countries what is preferred is a large deeply cupped oyster with plump white meat. Though consumers like to eat live oyster meat raw, sale of shelled oysters (live) become difficult if the marketing centres are at great distances. It is very expensive to deliver live oysters to distant places, and the risk of mortality is also high when transported in dry conditions. A cheaper and more convenient way to deliver the oysters in the consumer market, is by shucking them and delivering them as raw, deep frozen, canned or smoked. Therefore, processing of oyster meat is essential. The producers and suppliers have to ensure uniformly good quality shellfish which are graded according to size and weight, by quality or by quantity.

PROCESSING

Certain standard techniques in processing and preserving of oysters are done before they are delivered for sale in markets. Shucked oysters are undoubtedly the most important form of oyster product and are relatively cheap, popular with customers, and potentially saleable anywhere. Shellfish offer a wider choice of recipes to the modern housewife who likes to offer variety in the family menu. The processing of molluscan shellfish is of great importance and there is wide scope for further improvement. Shucking is done manually and gaping is effected mechanically or chemically. Recently shell valves are being opened utilising microwave energy.

Manual shucking: Manual shucking is generally used only by smaller companies where quality is more important than quantity. For manually opening the oysters special tools and great skill are required. The shucking knife is fiarly long to provide leverage to turn the valves open after its sharp blade-like edges cut the adductor muscles. Gloves and finger stalls are needed to protect the fingers from getting hurt by the sharp edges of the shells and the process is slow.

Mechanical shucking: Although many attempts have been made to develop a mechanical method for shucking oysters, the lack of uniformity in size and shape of oysters, have made a purely mechanical system difffi-cult and no suitable method has yet been devised. But mechanised conveyor belts have been used by some of the companies to get the oysters to the shucking tables and another conveyor belt system to remove the meat and waste shell from the shucking table. In this process first the oysters are steam-opened. While the oysters are steamed, the juices and flavour of the oysters are considerably lost. Hence during steaming the temperature is maintained at a level just enough to relax the adductor muscle and to open the valves and not to cook the meat. This blanching process prevents slime formation during storage and it firms the meat enough to make it attractive. This process is essential prior to freezing.

Chemical process: Chemicals can be used to cause the adductor muscle to relax so as to enable the shucking knife to be introduced more easily. This is done by placing the live oyster in water to which acetic acid or hydrochloric acid is added. A chemical reaction with the lime salts of the oyster shell releases Co_2 and the oysters gape widely.

<u>Utilisation of microwave energy</u>; Research carried out at the National Marine Fisheries Atlantic Fishery Products Technology Center in Glouscester, Massachussets, U.S.A., has shown that microwave energy (2450 MHz) can be used to increase the productivity of shucking oysters and other bivalves. A short microwave treatment relaxes the muscle of the bivalve without cooking the meat, resulting in the visible loosening or opening of the shell valves. This allows easy separation with a shucking knife and greatly facilitates the shucking process, retaining the flavour intact.

PRESERVATION

Once the oysters are opened and shucked, they are marketed as raw, deep frozen, pickled, canned and smoked for which different methods of preservation are followed.

<u>Refrigeration</u>: The important factors involved in the storage of freshly shucked oysters are (1) the speed of cooling after shucking and (2) the temperature at which it is stored. Uncooked, shucked oysters can often be stored for two weeks at 1.7°C. However cooked and shucked oysters can be stored for a longer period. When heated at 65 to 70 °C for 30-50 minutes it can be stored well for nearly two months at a temperature of 0°C. If uncooked meat is to be frozen, it must be protected from loss of moisture and contact with air during storage so as to avoid desication and discolouration. Reasonably quick freezing is needed and the frozen meat should be stored at -18°C. If oysters are stored at -21°C storage life of upto one year may be obtained. Before freezing the oysters are packed in wax coated carton with polyethylene lining.

<u>Canning</u>: Canning is one of the most popular methods of preparing the bivalve for market. First the shucked oyster meat is washed well with a jet of water, preferably with good quality brine to remove shell bits and any other adhering particles on a perforated strainer of stainless steel. The washing should not exceed three minutes and thereby osmotic loss of tissue fluids is avoided. Immediately after water is drained and the meat is graded according to size. In some

factories prior to shucking the oysters are dipped in hot(60.0-65.5°C) water and immediately chilled similar to pasteurisation. A good blanching renders the product with better shape and flavour. There are various ways of cooking oysters prior to canning, some firms use the live steam method instead of water and the process lasts 30 minutes at 115°C. Another method is to place the meat on perforated trays and have them cooked in brine for 4-8 minutes. After cooking the oysters are to be filled in suitable cans and sealed. Before sealing care must be taken to leave a headspace below the lid and pure sea water or purified brine or salted sweet water is added. After the cans are sealed they are sterilized at 121°C for 10 minutes or at 115°C for 25 minutes.

Canned smoked oysters: Oysters which have been steamed open or which have been shucked fresh and partially cooked are used for smoking. They are rinsed for 5 minutes in a 2.5% brine solution and then spread in a single layer on a 1" mesh galvanized wire tray and immediately transferred to the smoking room (temperature 48.9°C). In about 4 hours at this temperature the meat though remain intact attain brown colour. Smoked oysters are packed in $\frac{1}{2}$ pound (227 g) flat cans filled with $1\frac{1}{2}$ fl. oz. (29.6 ml) of salad oil and exhausted for 15 minutes at 4.5 - 5.5 kg pressure in the retort. After double seaming the cans are processed in a retort at 115.5°C for 60 minutes.

Oyster stew: Oysters that are too large are used for the preparation of oyster stew. They are precooked, chopped into small pieces and prepared with milk, spices and butter followed by standard canning techniques.

In addition to the above products, oyster chowder, oyster soup, oyster sticks and oyster pickles are some of the common preparations in the market. But the demand varies from place to place and varies with consumer's preferences.

Frozern oysters: This is a new method of processing oysters and as yet a perfect method is to be adopted. A slimy secretion is produced when the product is thawed and attempts have been made to overcome this by preliminary blanching and also by freezing individual oysters. Intensive research work on this type of processing oysters is going on at various oyster processing centres.

MARKETING OF BIVALVES

Marketing has always been the weak link in the shellfish industry. It is of no use producing large quantities of shellfish if they cannot be sold. Several factors affect the marketing efficiency of bivalves. Apart from biological and seasonal aspects it is also affected by the lack of transport and storage facilities, remoteness of marketing centres, lack of consumer education and publicity. In developed countries many of such impediments have been overcome and the shellfish industry thrives well by an organised system. They are marketed in a number of ways such as (1) direct to consumer, (2) to retailers (3) to whole-sale fish dealers (4) to other oyster producers and (5) to processors (canners). However in developing countries shellfish trading is still in the infant stage. Although areas for potential shellfish production are available they remain still unexploited for want of necessary domestic market.

During the journey to the market if proper precautions are not taken, it is often found that oysters get contaminated by pathogenic and nonpathogenic organisms. This weakens public confidence in the product and is often confused with primary pollution. Contamination risk increases with the distance the shellfish have to travel.

The consumer's attitude towards food is always on the subjective plane. Taste and quality are two important aspects for a food item to draw the notice of the general public. For a new and seemingly disagreeable food the industry should present it in the most appetising form possible. After all, man's food preferences are learned and not inherent. In this respect food processors could achieve desirable results by preparing suitable gourmet dishes on molluscs and popularising them.

In most of the countries at present the publicity for sea foods is mainly restricted to professional press and leaflets. Shellfish products are advertised in most of the fish trade journals, but such publications are not normally read by the public at large and are directed at the retailer more than the consumer. Periodic advertisements in newspapers and weeklies and occassionally featuring in television would create an awareness among the public.

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ECONOMICS OF PRODUCTION AND SOCIO-ECONOMICS OF CULTURE

P.S. KURIAKOSE

ECONOMICS OF PRODUCTION

Coastal cultivation of edible molluscs is an efficient method of converting marine phytoplankton into nutritious and palatable food. The economic components of different systems of culture varies considerably depending mainly on the various methods adopted in the culture systems. The cost of labour and raw-materials required for culture also affect production cost. As in any other commercial venture the molluscan culture farm also depends on the profit it earns. Profit for a particular period is the excess of revenue it received for the commodity it produced over the total values of the services of the resources used in the production process during that period. Therefore, the economic evaluation of a culture farm is the evaluation of the profit or loss, which is the difference between the farm's total revenue and total cost for particular period.

As an example the economics of an experimental mussel culture carried out in the open sea at Calicut is given below. Since the life of one raft is 3 years the income statement is given for 3 years.

CAPITAL COST OR FIXED COST OF ONE RAFT FOR 3 YEARS

	Rs.
1. Teak poles 10 Nos. @ Rs.25/- per pole	250.00
2. Bamboo poles 12 Nos. @ Rs.15/- per pole	180.00
3. Anchors 100 kgs. 2 Nos.	1000.00
4. Anchor chain 100 kgs.	1400.00
5. Nylon ropes 6 kgs.	170.00
6. Shackles etc.	250.00
Total	3250.00

RECURRING EXPENDITURE OR VARIABLE COST

1. Oil drums 5 Nos. @ Rs.100/-	500.00
2. Coir ropes 300 kgs.	1500.00
3. Knitted cotton cloth	400.00
4. Seeding expenditure	200.00
5. Expenditure for farm management	400.00
Total	3000.00

ie., The total expenditure for 3 years
3250 + (3000 x 3) = 12250.00

Salvage value of the raft after 3 years	Rs. 500.00
Depreciation of the raft after 3 years	Rs.2250.00

One mussel culture raft can hold 100 mussel culture ropes and the average production per rope in one year 50 kgs. of mussels. So the total yield from a raft per year

= 50 x 100 = 5000 kgs. of mussels.

Average price for 1 kg. mussels = Rs. 1.25

The total return for 1 year 5000 x 1.25 = Rs. 6250/-

ie., The average return for 3 years = 6250 x 3 = Rs. 18750/-

Total profit at the end of 3 years =

Total revenue - (Total cost including depreciation -- Salvage value) = 18750 (12250 + 2250 - 500)

= 18750 - 14000 = 4750.00

Therefore the profit for 3 years per raft = Rs.4750/-

SOCIO-ECONOMICS OF CULTURE

The importance of coastal aquaculture in the context of augmenting production of economically important molluscs and improving rural economy was recognised only very recently in India. Our country possess the essential basic resources required for immediate development of coastal aquaculture. The potential coastal waters available in our country includes about 8.9 million hectare of productive inshore waters. A variety of suitable molluscs (Mussels, Oysters, Pearl oysters and Clams) possessing high productive capacity, short larval development, fast rate of growth, and physiological feature to adjust to wide changes in environment are available in our coastal waters. As the active fishermen engaged in the coastal fisheries form only 21% of the total marine fisher population in the country, there are large number of unemployed and underemployed fishermen who could advantageously take up the coastal aquaculture. The impact of introducing any labour intensive, income generating marine farming programme aimed at uplifting the socio-economic condition of the fishermen has to be properly assessed by the farm scientists before embarking on large scale propagation of the venture in question over wider areas. In a vast country like India, this aspect has to be studied region-wise since condition differ from one place to another. For example mussel culture can be profitably carried out along the Malabar coast. In this region nearly 3000 fishermen families depend mainly on mussel fishing. Their average family income is less than Rs. 2000 per annum. A family may be comprised of about 5 to 10 members out of which mostly a single member may be engaged in mussel fishing. They can easily practise mussel farming if they are given some preliminary financial assitance for the fabrication of rafts. During their normal fishing, seed collection can be carried out without any extra effort. Seeding can be done at home with the assistance of all the members of the family including women and children. The seeded ropes can be suspended fromthe rafts by the fishermen while going for mussel picking in the next day morning. Thus mussel culture can be carried out by these families without much extra effort. In the same way oyster culture can be practised at Tuticorin by fishermen engaged in traditional fishing and clam culture at Kakinada. Since the availability of the seed is the main factor in the success of the molluscan culture, any economically important molluscs can be cultured in areas where seed is available. Since the production rate in almost all molluscan culture is high and growth very fast, the culture operations will give quick results. Harvesting can be adjusted according to the market demand for better profit. This generates more employment opportunities and improved economic condition of the fishing village.

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CULTURE OF THE BROWN MUSSEL

AT VIZHINJAM.

K.K. APPUKUTTAN

"Raft culture" has been adopted for the farming of brown mussel both in the bay and in the open sea. Rafts of different sizes, ranging from 6 x 6 metres to 8 x 8 metres were fabricated with teak and bamboo poles lashed by coir or nylon ropes. Metal drums of about 200 litres capacity, treated for anticorrosion, were used to give buoyancy to the rafts. The rafts were moored by anchors, by required length of anchor chains. While the rafts could be maintained in the bay throughout the year, those in the open sea could be kept in position only during the calm season from January to May. The depth of Vizhinjam Bay varies from 10 to 15 metres and the bottom is muddy.

Open-sea mussel culture experiments were carried out about 1 - 2 km away from the shore at depths ranging from 15 - 25 metres. The sea is usually calm from the end of December to the end of May when the rafts could be kept in position. Rest of the year, the sea is subject to heavy wave action making it difficult to maintain the rafts.

Seed availability

Brown mussel starts spawning in May which lasts till September. The period of peak spawning is July-August. Settlement of mussel seed begins by July and dense settlement of seed is seen during September-October. The young mussel attains the mode of 15 - 19 mm in length in July, 25 - 29 mm in August and 30 - 34 mm in September. Seed in the size range of 20 - 35 mm were collected from the natural beds from September to November. The rocky area between the Light House and the breakwater of Vizhinjam Bay, Avaduthura and Mulloor, Enayam, Colachel, Muttom and Neendakara are all good seed collection areas. Good spatfall also occurs inside the bay on split ropes suspended from rafts. The seed thus collected on the ropes were also used in the farm.

Seeding

The seed were washed in sea water and the fouling organisms were removed. They were then wrapped around a rope and secured by cotton netting or bandage cloth. Both coir ropes and nylon ropes were used for seeding, but nylon rope was found to be more economical considering the longevity of the rope. The length of the ropes seeded ranged from 5 to 10 metres. To avoid slipping of seed in the initial stage, wooden pegs were inserted at regular intervals in the rope. The average weight of mussel seed per metre length of rope (seeded portion) ranged from 1.4 to 2.0 kg. The seeded ropes were suspended from the rafts.

Growth of mussel and production

In the Vizhinjam Bay, the brown mussel reaches the size of 55 - 60 mm in 8 months, giving an average growth of 2.94 mm per month. In 1979 the growth rate observed was 3.54 mm per month. The size 55 - 60 mm is marketable. The ratio of flesh weight to shell-on weight is 41.31% in May. After June, due to influx of freshwater into the bay and also increase in weight of ropes, there is a tendency for the farm-grown mussels to fall out. Hence May-June appears to be the appropriate time for harvesting the tended stock.

In the open sea culture experiments the growth of mussel was relatively faster. A modal size of 60 - 65 mm was attained in 5 months recording a growth rate of 5 mm per month. The flesh weight constitutes 43.33% of the total weight of mussels in May.

The average rate of production was 10 - 12 kg of mussel per metre length of rope in the bay in 8 months and 15 kg in the open sea in 5 months.

Prospects and problems

In the existing sustenance fishery for the brown mussel at Vizhinjam the production ranges from 50 - 150 tonnes a year. Based on the results obtained in experimental culture of the mussel in the bay as well as the open sea, it is possible to increase mussel production in the area by adopting raft culture techniques. One major area of current research relates to developing suitable methods for year round operations in the open sea since the growth of mussel and production rate are higher in the open sea than in the bay. Experiments on this aspects are being carried out at Madras, Calicut and Vizhinjam.

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THE CULTURE OF PHYTOPLANKTON

D.C.V. EASTERSON

The bivalves during development depend mainly on lipids available in the egg for their energy requirements, while as adults rely chiefly upon carbohydrates. The oyster larvae at the time of hatching have some quantity of lipid left to meet the initial metabolic requirements. With the initiation of feeding on carbohydrate rich algae they switch over to carbohydrate based energy metabolism. The smooth switching over of the energy source and the easy availability of the choice food algae are the two vital factors which determine the survival of the larvae.

The bivalve larvae are pelagic, fine particle filter feeders having opposed ciliated bands. They feed on very small sized unicellular algae. Therefore in the hatchery production of molluscan seed, culture of unicellular algae come to occupy a pivotal position.

Choice of the algae

Not all unicellular algae suit the purpose of being a larval food organism. It depends on the following factors. The phytoplankters in general are known to release certain chemicals as metabolic bye products into the medium called extra cellular metabolites or exocrines. The exocrins of many algae contain toxins, the quantity of which depends on the density of the algae. Apart from this, the algal cell boundaries become infested with toxic bacteria, whereby even otherwise non-toxic algae may acquire toxic quality. The cell wall of some of the algare are very thick and resist digestion. Therefore algae with thin or no cell wall are preferred. Another important factor is the size of the cell. The algae should be very small so that the larvae are able to swallow them. In the following table the algae and their food value for the bivalve larvae have been compiled.

Table 1. Food value of various algae to the bivalve larvae.

Algae	Food value	Remarks
Chlorophyceae		
Coccomyxa sp.	None	Thick cell wall
Chlorella stigmatophora	"	"
C. marina	"	"
Nannochloris atomus	Low	
Dunaliella tertiolecta	Low	
D. euchlora	Medium	
Prasinophyceae		
Pyramimonas grossi	Good	Difficult to culture
P. ovata	High	
Tetraselmis suecica	High	
T. marina	Medium	
Micromonas pusilla	High	
Haptophyceae		
Isochrysis galbana	Very high	No cell wall
Dicrateria inornata	"	Difficult to culture
D. gilva	"	"
Chrysochromulina spp.	High	"
Prymnesium parvum	Poinsonous	
Chrysophyceae		
Chromulina pleiades	High	Difficult to culture
Monochrysis lutheri	Very high	No cell wall
Cryptophyceae		
Crytochrysis rubens	Medium	Difficult to culture
Cryptomonas acuta	"	
Hemiselmis rufescens	Medium	
H. virescens	Low	
Cyanophyceae		
Synechococcus elongatus	None	
Bacillariophyceae		
Phaedactylum tricornutum	Low	
Chaetoceros calcitrans	Very high	Difficult to culture
Cyclotella nana	"	"
Skeletonema costatum	Medium	"

The nutritional value of algae is not always uniform, it is a function of culture conditions. Further it is also found that mixture of different algae often give better larval growth. In order to keep the concentration of the exocrines low the algal density should be maintained at an optimum and further a constant flow of water is also helpful.

Glassware

The glassware used in phytoplankton culture should be of borosilicate (Corning or Pyrex) and neutral in reaction. First the new glassware are cleaned in tap water to remove spores and dust from the packing materials and then soaked in 1% hydrochloric acid to remove any free alkali present. Afterwards washed in laboratory detergents (teepol or lab wash), many times with tap water and finally rinsed in distilled water for a number of times. Since copper is toxic, the distilled water prepared from stainless steel or glass still should be used. It is found that chromium ions are toxic and get absorbed on to the glasswares. Therefore chromic acid should not be used to clean the glass vessels. Instead concentrated H_2SO_4 saturated with L.R. grade sodium nitrate or hot nitric acid should be used. Finally the culture vessels are allowed to dry well and it is preferred to heat them at 70°C for atleast 1 hr. For large scale culture we use Hoffkins flasks and glass carbouys.

Sea water

Though artificial sea water is used in many laboratories natural sea water is preferred. Sea water collected from the offshore regions and allowed to age is the best suited. The sea water is first filtered through cotton wool supported on a nylon mesh and then through a whatman No. 1 filter paper. Whatman G.F.C. filter paper can also be used along with suction. For better results Millipore membrance filters are recommended. The filtered sea water is autoclaved at 2 atm for 1 hr.

ENRICHMENT MEDIA

For special purposes culture media are used. But generally sea water to which nutrients have been added, known as enrichment media are used. There are so many. In our laboratory the following are being used.

1. Erdschreiber medium

Sodium nitrate ($Na\ NO_3$)	0.100 g
Disodiumhydrogen phosphate ($Na_2HPO_4 . 12H_2O$)	0.020 g
Soil extract	50 ml
Sea water	900 ml
Distilled water	100 ml

Soil extract is prepared as follows: Good garden soil is collected, allowed to dry, the large stones are hand picked and crushed well. The crushed sample is finely seived. This fine powder is autoclaved at 120°C for 20 minutes with twice its volume of distilled water and allowed to sediment. The supernatant yellow-brown coloured water is decanted and stored in a refrigerator for use.

In preparing the media, sea water along with sodium nitrate and acid phosphate is autoclaved, in which the salts may precipitate, and the addition of distilled water the precipitate dissolves. To this cool solution soil extract from the regrigerator is added.

2. Miquel's medium

Solution - A

Potassium nitrate (KNO_3)	20.2 g
Distilled water	100 ml

Solution - B

Sodium acid phosphate monobasic($Na_2HPO_4 .12H_2O$)	4 g
Calcium chloride ($Ca\ Cl_2 .6\ H_2O$)	4 g
Conc. hydrochloric acid (HCl)	2 ml
Ferric chloride ($Fe\ Cl_3$)	2 g
Distilled water	98 ml

Culture medium:

Solution A	0.55 ml
Solution B	0.5 ml
Sea water	1 litre

3. Modified Miquel sea water- Shiraishi's medium

Solution -A - as given above

Solution -B

Sodium acid phosphate ($Na_2HPO_4.12H_2O$)	4 g
Calcium chloride ($Ca\ Cl_2.6\ H_2O$)	4 g
Hydrochloric acid	2 ml
Distilled water	80 ml

Solution-C (Mineral mixture)

Disodium ethylene diamine tetra acetic acid(EDTA)	300 mg
Ferric chloride ($Fe\ Cl_3$)	8 mg
Manganese chloride ($Mn\ Cl_2.\ 4H_2O$)	12 mg
Zinc chloride ($Zn\ Cl_2$)	1.5 mg
Cobatous chloride ($Co\ Cl_2.\ 6H_2O$)	0.3 mg
Copper sulfate ($Cu\ SO_4.\ 5H_2O$)	0.12 mg
Ortho boric acid (H_3Bo_3)	60.0 mg
Distilled water	100 ml

Solution-D (Vitamin mixture)

Vitamin B_{12}	0.1 mg
Thiamin	10 mg
Biotin	0.1 mg
Distilled water	100 ml

Store in a refrigerator

Culture medium

Solution A	2 ml
Solution B	1 ml
Solution C	2 ml
Solution D	1 ml
Sea water	1 litre
Tris buffer	50 mg

4. Walne's enrichment medium

Solution-A

Ferric chloride ($Fe\ Cl_3.6H_2O$)	2.6 g
Manganese chloride ($Mn\ Cl_2.4H_2O$)	0.72 g
Orthoboric acid (H_3BO_3)	67.20 g
Sodium EDTA	90.00 g
Dibasic sodium acid phosphate ($Na\ H_2PO_4.2H_2O$)	40.00 g
*Potassium nitrate (KNO_3)	200.00 g
Distilled water	2 litres

Solution-B

Zinc chloride	2.1 g
Cobalt chloride	2.0 g
Ammonium para molybdate $(NH_4)_6\ Mo_7O_{24}.4H_2O$	0.9 g
Copper sulfate ($Cu\ SO_4.5H_2O$)	2.0 g
Distilled water	1 litre

Acidify with HCl to obtain a clear liquid

Solution-C

Vitamin B_{12}	10 mg
Thiamine	200 mg
Distilled water	2 litres

To be stored in a refrigerator

Culture medium:

Solution A	10 ml
Solution B	1 ml
Solution C	1 ml
Sea water	10 litres

*Dr. Walne has given $Na\ NO_3$

Chelaters

Chelaters are used in the culture medium to avoid heavy precipitation of metals whereby avoiding toxicity. The addition of a chelating agent such as EDTA to the sea water sets up equilibria in which cations compete for available EDTA bonds, while enough ions are released to meet the needs of the growing cells.

ISOLATION OF ALGAE

At the onset autoclaved 1.5 - 2.0% agar solution prepared in desired culture medium is poured in autoclaved petridishes and kept ready. The heat liable nutrients are to be poured after cooling. The algae from the sea water suample is concentrated either by sedimentation or by centrifugation and examined for the presence of the desired alga. In case the wanted alga is present a drop of algal concentrate is taken in a platinum wire loop and streaked over the agar in a zigzag pattern. Then the petridishes are inverted and kept under or above cool white fluorescent light. Dust free air conditions rooms are preferred. The petridishes are periodically examined for growth. Different algae are distinguishable in the form of colonies. Each clean patch or algal cells are picked up with a sterile wire loop and second agar plating is done. This process is continued until a single species of algal cells are obtained. Finally this pure culture is transfered to the liquid media. Instead of petridishes slant cultures can also be done. Other methods of isolation and purification are pipette method and by using antibiotics.

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SPECIAL LECTURE

PROBLEMS RELATED TO SEED PROCUREMENT FOR CULTURE OF MARINE EDIBLE BIVALVE MOLLUSCS: CRASSOSTREA MADRASSENSIS AND MYTILUS (=*PERNA*) *VIRIDIS*

K. VIRABHADRA RAO

Procurement of adequate quantities of seed is an essential primary step in undertaking culture practices of economic species of bivalve molluscs. This applies not only in respect of molluscan species but equally well to all other aquatic living resources as the crustaceans and finfishes.

Procurement of seed helps establishing fresh farms in suitable grounds having similar environmental conditions as the original habitat or planting them in the existing farms at favourable locations to substantially increase the yields. It helps promotion of export trade in selected varieties possessing qualities of consumer preferences. Seed occupy much less space and withstand the strains of transport better then the adult shellfish. Seed in some can be conditioned for exposure over tolerably long periods of time outside water to enable their being carried to long distances as from one country to another. Seed can be collected from natural habitats using appropriate methods or produced in hatcheries by employing advanced scientific techniques of induced breeding by suitable means and rearing of the resultant larvae to the stage of settlement as seed or spat feeding them on selected species of algal cultures. Although the methods for these purposes developed outside this country are broadly known, the requirements of the individual species vary a good deal and the techniques have therefore to be modified and perfected for the local species to respond favourably.

COLLECTION OF SEED FROM NATURAL SOURCES

Seed from well established natural shellfish beds is usually abundant but their satisfactory procurement depends upon many factors. The farmer should have precise knowledge of where, when and how best to collect the seed of the species in question.

Settlement of oyster spat on cultch: Much research has gone into problems related to oyster culture in France, England, United States of America, Canada, Australia, Japan, Philippines and other maritime countries where certain species are regularly cultured, viz., Ostrea edulis and Crassostrea angulata in Europe, C. virginica and /@ C. gigas in Japan and C. commercialis in Australia. C. madrasensis is being cultured in India in recent years on quite a small scale. Faced with the problem of denudation of once productive beds, France was the first country to have successfully established oyster culture on an industrial basis as early as the middle of nineteenth century. It was recognised that collection of seed was an important aspect of culture. Wooden planks coated with pitch, other materials, untreated roofing tiles, and roofing tiles with a coating of lime and sand were tried and of these the last mentioned item proved to be efficient for after spat setting and a period initial growth, the spat could be flaked off and the tiles recoated with lime mixture to be used over again. Japan used mostly bamboo twigs fixed in tidal flats or scallopshells or even oyster shells strung on wire in garland fashion and fixed on stakes in suitable locations. In United States of America and Canada and also in Europe mostly dead oyster shells are made use of. In Australia spat are caught on stones spread over grounds in shallow waters. The choice of cultch depends to a large extent on the local availability of the material obtainable at reasonably low cost. Cultch should be clean for the larvae to settle and set as spat.

Cultch should be laid at appropriate time when the larvae are big enough to settle. If it is placed too early in water silt would settle and render it unsuitable for spat settlement, and if it is

/@ C. gigas in the United States of America and Canada, placed late the absence of the larvae in the environment would defeat the very purpose for which the cultch is laid. The breeding period or periods should be correctly assessed. In temperate waters rise in water temperatures gives an indication of approaching breeding time. After spawning in the case of oviparous species or swarming in the larviparous ones, two to three weeks time would be required for completing the larval development to attain the partly creeping and partly swimming stage known as the pediveliger which now settles on the cultch laid or in the absence of it on any hard material at the substratum and explores the spot for a while creeping by its foot. If the spot is clean it moves to its under-surface and attaches itself with the left valve to the surface of adhesion, fixation being secured by a rapidly hardening exudation from a gland at the foot base. Internal changes follow rapidly and the spat thus settled is a miniature oyster fixed to one spot.

The location where good setting takes place in the neighbourhood of oyster beds are in the direction towards which currents flow carrying the larvae and these have to be ascertained while laying the cultch. Favourable localities for spat setting are usually several in the vicinity of a single large bed. Cultch has therefore to be laid in several places simultaneously to obtain adequate quantities of spat.

Spawning or swarming of the adult oysters, rate of development duration of larval life, and setting intensities are determined by factors like fluctuations in water temperatures, marked though not small changes in salinity media, availability of food and changing phases of the moon. In the backwaters and estuaries seasonally cut off from the sea by sand bars, communication established with the sea after the monsoon rains promotes breeding and larval setting. Information centres for collection of relevant environmental data and reporting the same to aquaculturists as is being done in Japan would help a great deal to undertake timely field operations.

Crassostrea madrasensis occurring on the southern and central regions of the east and the west coasts is an oviparous species. There are no larviparous edible oyster species of commercial importance in the Indian waters. The spat are collected on lime and sand coated tiles and reared in trays in the well laid out experimental oyster farm of the Central Marine Fisheries Research Institute at Tuticorin where the adult marketable size is attained in about a year. The Japanese oyster Crassostrea gigas is introduced into the United States, Canada, Central and South America as well as some of the European countries because of its faster rate of growth than the indigenous species in those countries. Conditioning the spat of the Madras oyster for transporting and marketing them in other oyster growing countries may be tried because it grows even faster than C. gigas.

Seed of the sea mussel: The mussels cultured in Europe are the Atlantic species Mytilus edulis and the Mediterranean species M. galloprovincialis. On the Pacific coast of North America occurs M. californianus and off Japan M. crassitesta, the exploitation of both of which is low due to consumer preference for other bivalve species available in abundance. Among other mussel species are the green mussel, Mytilus viridis (Syn. Perna viridis) and the brown mussel, P. indica both of which are regularly utilized as food in India by the coastal populations who have developed a liking for them and the mussels are being cultured on scientific lines to a limited extent in demonstration farms of the Central Marine Fisheries Research Institute's Research Centre at some places both on the east and the west coast of the country (Madras, Calicut and Vizhinjam). M. viridis extends its distribution beyond the Indian territory to Singapore where attempts are made to culture the species.

In France where mussel culture is an ancient practice seed collection is resorted to by the "bouchot" system of culture with twigs interwoven in V-shaped fashion in the muddy tidal flats parallel to coast line. The seed setting on them grow not only very fast, but they are also free from the attacks of predators and pests which normally take a large toll when they are lying on the substratum. Along the Northern coast of France stout 4 m. long oak poles are used as stakes. Ropes upon which mussel seed are allowed to set are spirally twisted round the poles. As mussels grow, thinning is done. To prevent the mussels falling off they are put in narrow long net bags which are in turn tied to the poles. This helps the younger mussels time enough to secure fresh attachment by their byssus threads.

The mussel culture industry of Spain has made rapid strides since the Post-Second World War years when they adapted the raft culture method in the very productive waters of the Galician Bays and her present annual production has come to rank the highest among the mussel producing countries of the world. The rafts are wooden platforms mounted on sturdy floats (fibreglass mold). They bear wooden poles fixed to frame work and they jet out to support ropes which hang down into waters. The smaller rafts (20 m x 20 m) support suspension of 500 ropes each and the larger ones upto 1000 ropes. Seed settle on them and grow on these ropes. When setting is poor seed from elsewhere are supplemented.

In Philippines seed are carefully hand-picked from the natural environment by cutting out the byssus but not by pulling them out of their attachment. They are put in bamboo trays along with some cultch and the trays are fixed to bamboo poles above the level of the bottom of the bay in shallow waters in such a way that they are always immersed in water even at low tides.

In our waters mussels seem to breed round the year but with a peak season of intensive reproduction followed by profuse seed setting. Based on observations so far made it is now known that this period of abundant seed setting differs in different regions along the coasts. The seeds are at present collected from natural grounds by hand-picking after the period of intense spat settlement.

RAISING THE SEED BY EMPLOYING HATCHERY TECHNIQUES

In the United States of America, Canada, Britain and Japan large scale production of seed under fully controlled conditions especially of the edible oysters and to some extent other species of shellfish is being practised, employing hatchery techniques. Inducement of C. madrasensis and M. viridis to spawn, effecting fertilisation of the spawned out eggs, rearing of the larvae through various stages on a supply of food organisms and creating conditions for the grown up larvae to set as spat have been tried in our laboratories with a certain amount of success, but the techniques have to be standardised for production in the hatcheries on commercial scale. Spawning can be induced by physical, chemical, mechanical, electrical and biological stimulations but they are not universal in their application as the responses vary with the different species. A large number of algal cultures are generally used for feeding the growing larvae, of but all are not equally suitable for different /@ need preliminary investigations. With the adequate laboratory and field facilities that are being built up at the CMFRI it is possible to initiate and carry out successfully hatchery techniques for augmenting oyster and mussel production.

/@ shellfish species. These and many other problems

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LITERATURE SUGGESTED FOR

FURTHER READING

ABBOTT, R.T. 1974. American Sea Shells. Van Nostrand Reinhold Company, New York. 668 pp.

ABRAHAM, K.C. 1953. Observations onthe biology of Meretrix casta (Chemnitz). J. Zool. Soc. India, 5: 163 - 190.

ALAGARSWAMI, K. 1966. On the embryonic development of the squid (? Sepioteuthis arctipinnis Gould) from the Gulf of Mannar. J. mar. biol. Ass. India, 8(2): 278 - 284.

__________ 1966. Studies on some aspects of biology of the wedge clam Donax faba Gmelin from Mandapam coast in the Gulf of Mannar. J. mar. biol. Ass. India, 8(1): 56-75.

__________ 1970. Pearl culture in Japan and its lessons for India. Proc. Symp. Mollusca, Part III: 975 - 993. Marine Biological Association of India, Cochin.

__________ AND K.A. NARASIMHAM 1973. Clams, cockle and oyster resources of the Indian coasts. Proc. symp. Living Resources of the Seas around India, pp. 648 - 658. Central Marine Fisheries Research Institute, Cochin, India.

__________ AND S.Z. QUASIM 1974. Pearl culture - its potential and implication in India. Indian J. Fish., 20(2): 533- 550.

ANSELL, A.D, P. SIVADAS, B. NARAYANAN AND A. TREVALLION 1972. The ecology of two sandy beaches in south west India III Observations on the population of Donax incarnatus and D. spiculum. Mar. Biol., 17: 318-332.

__________, __________, __________ 1973. The ecology of two sandy beaches in south west India IV. The biochemical composition of four common invertebrates. Spl. Publ. dedicated to Dr. N.K. Panikkar. 333 -348. Marine Biological Association of India, Cochin, India.

APPUKUTTAN, K.K. 1977. Trochus and turbo fishery in Andamans. Seafood Export Journal, 9(12): 21 - 25.

ARNOLD, J.M. AND L.D. WILLIAMS-ARNOLD 1977. Cephalopoda: Decapoda. In: Reproduction of Marine Invertebrates, Vol. 4, Mollusca: Gastropods and Cephalopods. A.G. Giese and J.S. Pearse. (Eds) pp. 243 - 390. Academic Press.

AWATI, P.R. AND H.S. RAI 1931. Ostrea cucullata (The Bombay oyster). Indian Zool. Mem., (3): 107 pp. Methodist Publishing House, Lucknow.

BARDACH, E.J, J.H. RYTHER AND O. Mc LARNEY 1972. Aquaculture. The farming and Husbandry of Freshwater and Marine Organisms. pp. 674 - 789. Wiley - Intersience, New York.

BLACKWELDER, R.E. 1967. Taxonomy. John Wiley, New York.

CHEN, T.P. 1976. Aquaculture practices in Taiwan. 162 pp. Fishing News (Books) Ltd; London.

DAVIES, G. 1968. Mussels as a world food resource. Proc. Symp. on Mullusca, Part III: p 873 - 884. Marine Biological Association of India, Mandapam Camp, India.

DAVIS, H.C. 1969. Shellfish hatcheries - present and future. Trans. American Fish Soc, 98: 743 - 750.

DURVE, V.S. 1964. Preliminary observations on the seasonal gonadal changes and spawning in the clam Meretrix casta (Chemnitz) from the marine fish farm. J. mar. biol. Ass. India, 8: 125 - 135.

________ AND S.K. DHARMARAJA 1963. A study on the dimensional relationship in the clam Meretrix casta (Chemnitz) collected from two localities, J. mar. biol. Ass. India, 7: 69 - 79

FISHERIES DEIVISION, MALAYSIA. 1972. Review of the status of coastal aquaculture in Malaysia. In: Coastal Aquaculture in the Indo-Pacific, T.V.R. PILLAY (Ed) pp. 52 - 59. Fishing News (Books) Ltd, London.

FURFARI, S.A. 1979. Shellfish purification: A review of current technology. In: Advances in Aquaculture, T.V.R. Pillay (Ed.) pp. 385 - 395. Fishing News (Books)Ltd, London.

GOPALAKRISHNAN, T.C, K.K.C. NAIR, M. GEORGE PETER, V.N. SANKARANARAYANAN AND T.S. SATYANARAYANA RAO. 1977. Major biochemical constituents of some faunal components of the Cochin backwaters. Indian J. Mar. Sci., 6: 151 - 153.

HANSON, J.A. 1974. Open Sea Mariculture 410 pp. Hutchinson and Ross.

HORNELL, J. 1909. Report to the Government of Baroda on the Marine Zoology of Okhamandel in Kattiawar Part I: 1-148. Williams and Norgate, London.

________ 1909. Report to the Government of Baroda on the prospectus of establishing a pearl fishery and other marine industries on the coast of Okhamandel Ibid., Part II: 1- 34. Williams and Norgate, London.

________ 1910. Report on the suitability of Pulicat Lake for oyster culture. Madras Fish. Investigations 1908, Madras Fish. Bureau Bull., (4): 1-23.

________ 1910. The practice of oyster culture at Arcachon and its lessons for India. Ibid., 2(5): 1-90.

________ 1916. A note on the edible oyster. Mar. Fish. Investigations in Madras 1914-15, Madras Fish. Dept. Bull., (8): 1 - 10.

________ 1918. The edible molluscs of the Madras Presidency. Madras Fish. Investigations 1917, Ibid., (11): 1 - 51.

________ 1922. The common molluscs of South India. Madras Fish. Investigations 1921, Ser.2, /(14): 97-215. /Ibid.,

IMAI, T. 1970. Aquaculture in shallow seas: Progress in shallow sea culture. 614 pp. Amerind Publishing Co. Pvt.Ltd., New Delhi.

IVERSON, E.S. 1968. Farming the edge of the sea. 301 pp. Fishing News (Books).Ltd., London.

JONES, S. 1950. Observations on the bionomics and fishery of the brown mussel (Mytilus sp.) at the Cape region of peninsular India. J. Bombay Nat. Hist. Soc., 47(3):519-528.

________ 1968. The Molluscan fishery resources of India. Proc. Symp. Mollusca, Part III: 906 - 918. Marine Biological Association of India, Mandapam Camp, India.

________ AND K. ALAGARSWAMI 1973. Mussel fishery resources of India. Proc. symp. Living Resources of the Seas around India, pp. 641 - 647. Central Marine Fisheries Research Institute, Cochin, India.

KORE, B.A. AND M.C. JOSHI 1975. Food of the squid Loligo duvauceli d' Orbigny. Proc. Indian Acad. Sci., 81 (1): 20 - 28.

KORRINGA, P. 1976. Development in Aquaculture and Fisheries. Elseveir, Amsterdam.

________ 1976. Farming marine organisms low in the food chain. pp. 243 - 253. Elsevier, Amsterdam.

KRISHNAKUMARI, L., M.D. RAJAGOPAL AND SUMITRA VIJAYARAGHAVAN 1977. Some aspects of biology and biochmistry of the backwater clam, Meretrix casta (Chemnitz). Mahasagar Bull. Nat. Inst. Oceanogr., 10: 157 - 163.

LEARSON, R.J. 1974. New methods of shellfish processing in the United States. In: Fishery Products, R. Kreuzer (Ed). pp. 160 - 167. Fishing News (Books) Ltd., London.

LING, S.W. 1972. A review of the status and problems of coastal aquaculture in the Indo-pacific region. In: Coastal Aquaculture in the Indo-Pacific, T.V.R. Pillay (Ed). pp. 2 - 25. Fishing News (Books) Ltd., London.

LOOSANOFF, V. AND H.C. DAVIS 1963. Rearing of bivalve Molluscs. Adv. Mar. Biol., 1: 1 - 136.

MAHADEVAN, S. AND K. NAGAPPAN NAYAR 1973. Pearl oyster resources in India. Proc. symp. Living Resources of the Seas around India. pp. 659 - 671. Central Marine Fisheries Research Institute, Cochin, India.

MANE, U.H. 1974. Growth and breeding habits of the clam Katelysia opima in Kalbadevi Estuary at Ratnagiri. Indian J. Fish., 21: 386 - 398.

________ 1974. The adaptations of the estuarine clam, Katelysia opima to the salinity fluctuations. Rivista di. Biologa, 67: 109 - 139.

________ 1975. Reproduction and breeding of the clam, Katelysia opima in the Kalbadevi Estuary at Ratnagiri, West Coast of India. Indian J. Mar. Sci, 4: 86 - 92.

________ 1979. Studies on the growth and density of the clam Paphia laterisulca at Kalbadevi estuary, Ratnagiri on the west coast of India. Malacologia, 18: 297 - 313.

MATTHESSEN, G.C. 1970. A review of oyster culture and oyster industry in North America. Contrib. Woods Hole Oceanogr. Inst., (2528): 1 - 52.

MAYR, E. 1942. Systematics and Origin of Species. Columbia University, New York.

MILNE, P.H. 1972. Fish and shellfish farming in coastal waters. 208 pp. Fishing News (Books) Ltd., London.

PILLAY, T.V.R. AND Wm. A. DILL 1979. Advances in Aquaculture. Papers presented at the FAO Technical Conference on Aquaculture, Kyoto, Japan, 26th May - 2 June 1976. 651 pp. Fishing News (Books) Ltd., Farnham.

NAGABHUSHANAM, R. AND P.M. TALIKHEDKAR 1977. Reproductive biology of the wedge clam Donax cuneatus. Indian J. Mar. Sci., 6: 35 - 38.

______ AND ______ 1977. Seasonal variations in proteins fat and glycogen of the wedge clam Donax cuneatus. Indian J. Mar. Sci., 6: 85 - 87.

NAIR, AIYYAPPAN. 1978. Production ecology of a tropical sandy beach at Benaulim, Goa. Ibid., 7: 163 - 167.

NAIR, S.G. DALAL AND Z.A. ANSARI 1978. Growth of the beam clam Donax incarnatus Gmelin from a sandy beach at Benaulim, Goa. Ibid., 7: 197 - 198.

NARASIMHAM, K.A. 1969. Studies on some aspect of biology and fishery of the cockle, Anadara granosa (Linnaeus) from Kakinada Bay. Proc. Symp. Mollusca, Part II: 407 - 417. Marine Biological Association of India, Mandapam Camp, India.

______ 1973. On the molluscan fishery of Kakinada Bay. Indian J. Fish., 20: 209 - 214.

______ 1980. Experimental culture of the blood clam Anadara granosa (Linnaeus). Proc. Symp. Coastal Aquaculture (in press). Marine Biological Association of India, Cochin, India.

NAYAR, K. NAGAPPAN. 1955. Studies on the growth of the wedge clam Donax (Latona) cuneatus. Linnaeus. Indian J. Fish., 2: 325 - 348.

______ AND S. MAHADEVAN 1973. Chank resources of India. Proc. symp. Living Resources of the Seas Around India, pp. 672 - 688. Central Marine Fisheries Research Institute, Cochin, India.

______ AND ______ 1974. Edible bivalves: clams and others. Bull. Cent. Mar. Fish. Res. Inst., (25): 40 - 53.

NOWAK, W.S.W. 1970. The marketing of shellfish. 263 pp. Fishing News (Books) Ltd., London.

OFFICE OF FISHERIES, REPUBLIC OF KOREA 1972. Present status and problems of coastal aquaculture in the Republic of Korea, In: Coastal Aquaculture in the Indo-Pacific, T.V.R. Pillay (Ed). pp. 48 - 51. Fishing News (Books) Ltd., London.

OOMMEN, V.P. 1976. Biology of the squid Loligo duvauceli d' Orbigny obtained in the night catches. Indian J. Mar. Sci., 5(1): 135 - 137.

__________ 1977. Studies on the food, feeding and fishery of certain cephalopods from the west coast of India. Bull. Dept. Mar. Sci., 8: 73 - 152.

PARULEKKAR, A.H, S.N. DWIVEDI AND V.K. DHARGALKAR 1973. Ecology of clam beds in Mandovi, Cumbarjua canal and Zuari estuarine system of Goa. Indian J. Mar. Sci., 2:122-126.

QUAYLE, D.B. 1969. Pacific oyster culture in British Columbia. Bull. Fish. Res. Bd. Canada, (169): 1- 192.

__________ 1971. Pacific oyster raft culture in British Columbia. Ibid., (178) : 1 - 34.

__________ AND D.W. SMITH 1976. A guide to oyster farming. 54 pp. Marine Resources Branch. Department of Recreation and Travel Industry. Victoria, British Columbia, Canada.

RANADE, M.R. 1964. Studies on the biology, ecology and physiology of marine clams. Ph.D. Thesis, University of Bombay, 266 pp.

__________ AND C.V. KULKARNI 1973. Observations on the behaviour of clams in waters of low salinity. J. Bombay Nat. Hist. Soc., 69 (3): 616 - 634.

RAO, H. SRINIVASA. 1928. A short account of the oyster industry in the islands of Bombay and Salsette. Ibid., 33 (4): 893 - 898.

__________ 1939. Consolidated report on the shell fisheries in the Andamans during the years 1930 - 35. 130 pp. Zoological Survey of India, Calcutta, India.

RAO, K. SATYANARAYANA 1967. Annual reproductive cycles of the wedge clams Donax cuneatus (Linnaeus). J. mar. biol. Ass. India, 19: 141- 146.

RAO, K. SATYANARAYANA. 1974. Edible bivalves: mussels and oysters. Bull. Cent. Mar. Fish. Res. Inst., (25): 4 - 39.

RAO, K. VIRABADHRA. 1951. Studies on the growth of *Katelysia opima* (Gmelin). Proc. Indo-Pacific. Fish. Counc. Sec., 11: 94 - 102.

__________ 1954. Biology and fishery of the Palk Bay squid *Sepioteuthis arctipinnis* Gould. Indian J. Fish., 1: 37 - 66.

__________ 1963. Edible molluscan shellfish of India. Indian Fish. Bull., 10(3): 23-27.

__________ 1966. Oysters. Wealth of India - Raw materials, 7: 202 - 207 Council of Scientific and Industrial Research, New Delhi.

__________ 1969. Molluscs have many uses. Indian farming. 29 (9): 41 - 45 & 62

__________ 1970. Pearl oysters of the Indian region. Proc. Symp. Mollusca, Part III: p 1017 - 1028. Marine Biological Association of India, Mandapam Camp, India.

__________ 1980. Induced spawning of the adult and laboratory rearing of the larvae of the edible oyster *Crassostrea madrasensis*. Symp. on coastal aquaculture. Abstracts: No: 317 : 186-187. Marine Biological Association of India, Cochin, India.

__________, K. KRISHNA KUMARI AND S.Z. QASIM 1976. Aquaculture of green mussel, *Mytilus viridis* L: Spawning, fertilisation and larval development. Indian J. Mar. Sci., 5: 113 - 116.

__________, K.A. NARASIMHAM AND K. ALAGARSWAI 1962. A preliminary account of the biology and fishery of the razor-shell *Solen kempi* Preston from Ratnagiri in Maharashtra State. Indian J. Fish., 9(2)A: 542 - 579.

__________ AND K. SATYANARAYANA RAO 1974. Pearl oysters. Bull. Cent. Mar. Fish. Res. Ins., (25): 84 - 105.

RICHARD, A. 1976. Lelevage de la seicha (*Sepia officianalis* L Mollusque Cephalopode). In: Proc. 10th European Symp. Mar. Biol., Vo. 1, Mariculture, G. Persoone and E. Jaspers (Eds.) p. 359 - 380. Institute for Marine Scientific Research Bredene, Belgium.

SARVESAN, R. 1969. Some observations on parental care in Octopus dollfusi Robson (Cephalopda: Octopodae). J. mar. biol. Ass. India, 9 (2): 203 - 205.

________ 1974. Cephalopods. Bull. Cent. Mar. Fish. Res. Ins., (25): 63 - 83.

SASTRY, A.N. 1968. The relationships among food, temperature and gonad development of the bay scallop Aequipecten irradians Lamarck Physiol. Zool., 41 (1): 44 - 53.

SATYAMURTI, S.T. 1952. The Mollusca of Krusadai Island (in the Gulf of Mannar). I. Amphineura and Gastropoda. Bull. Madras Govt. Mus., New Ser., Nat. Hist., 1(2), pt.6: 1 - 335.

________ 1956. The mollusca of Krusadai Island (in the Gulf of Mannar). II. Scaphopoda, Pelecypoda and Cephalopda. Ibid., New Ser., Nat. Hist., 1(2), pt.7: 1 - 263.

SILAS, E.G. 1968. Cephalopods of the west coast of India collected during the cruises of the research vessel "VARUNA" with catalogue of the species known from the Indian Ocean. Proc. Symp. Mollusca, Part I: 277 - 359. Marine Biological Association of India, Mandapam Camp, India.

________ 1969. Exploratory fishing by R.V. Varuna Bull. Cent. Mar. Fish. Res. Inst., (12): 86 pp.

________ AND K. ALAGARSWAMI 1967. On an instance of parasitisation by the pea-crab (Pinnotheres sp.) on the backwater clam Meretrix casta (Chemnitz) from India with a review of the work on the systematics, ecology, biology and ethology of pea-crabs of the genus Pinnotheres latreille. Proc. Symp. Crustacea, Part III: 1161 - 1227. Marine Biological Assisciation of India, Mandapam Camp, India.

SINDERMANN, C.J. 1970. Principal diseases of Marine Fish and Shellfish, 369 pp. Academic Press, New York.

________ 1979. Oyster mortality and their control. In: "Advances in Aquaculture" T.V.R. Pillay (Ed) - pp. 349 - 361. Fishing News (Books) Ltd., London.

SRIBHIBHADH, A. 1972. Status and problems of coastal aquaculture in Thailand. Ibid., In: Coastal Aquaculture in the Indo-Pacific. T.V.R. Pillay (Ed). pp. 74 - 83. Fishing News (Books) Ltd., London..

STEIN, J. (Ed) 1973. Handbook of Phycological Methods: Culture methods and growth measurements. Cambridge University Press.

SUMITRA VIJAYARAGHAVAN, M.V.M. WAFAR, P.G. JACOB, T. BALSUBRAMANIAM, M.D. RAJAGOPAL AND L. KRISHNA KUMARI 1975. Caloric values of estuarine and marine organisms from Goa. Mahasagar, Bull Nat. Inst. Oceanogr. 8: 9 - 14.

SUMMERS, W.C. 1971. Age and growth of Loligo pealei, a population study of the common Atlantic coast squid. Biol. Bull. 141: 189 - 201.

TALIKHEDKAR, P.M, U.M. MANE AND R. NAGABHUSHANAM 1978. Growth of the wedge clam Donax cuneatus at Mirya Bay, Ratnagiri. Indian J. Fish., 23 (1 & 2): 183 - 193.

UKELES, R. 1976. Cultivation of plants - Unicellular plants. In: Marine Ecology, O. Kinne (Ed) Vol. 3, Part I, pp. 367 - 466. John Wiley & Sons, London.

VENKATARAMAN, R. AND S.T. CHARI 1951. Studies on oysters and clams. Biochemical variations. Indian J. Med. Res., 39: 533 - 541.

WAINE, P.R. 1974. Culture of Bivalve Molluscs: 50 years experience at Conway. 173 pp. Fishing News (Books) Ltd., Surrey, England.

WELLS, M.J. AND J. WELLS 1977. Cephalopoda: Octopoda. In: Reproduction of Marine Invertebrates. Vol. 4. Mollusca: Gastropods and Cephalopods. A.G. Giese and J.S. Pearse (Eds) pp. 291 - 338. Academic Press.